technomedical visions

MAGNETIC RESONANCE IMAGING IN 1980S SWEDEN

ISABELLE DUSSAUGE

Division of History of Science and Technology
Royal Institute of Technology, KTH
SE-100 44 Stockholm, Sweden

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To Janne

preface

It is special and somehow uncanny to look at this book and attempt to see in it, again, what has long been an open-ended curiosity project, a steady company (quite often uninvited), a tenacious adversary and the unexpected start of many adventures. My years with this dissertation have been times of change, of personal, intellectual and geographical moves. There have been several lives within that life. People have made my world all this time. I feel indebted to many and most of all, grateful.

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I want to extend warm thanks to Anders Houltz, Anna Storm, Micke Nilsson and my beloved partner Janne Bromseth who have proofread important parts of this dissertation and contributed to make at least some sentences shorter ☺

Janne, this book is dedicated to you; it marks the beginning of another life. I would never have completed this without you. Not only have you commented this text many times and patiently helped me develop it. With your love, curiosity, smartness, and commitment to live with all your heart and soul you have opened up whole new worlds to me. You have inspired me, supported me, fascinated me, loved me, challenged me, made me laugh and travel, and made me feel human during these intense years of work. And you have shown me the way to an independent, freer (and more fun!) life.

I am eagerly looking forward to the continuation of it all.

Stockholm, February 2008
Isabelle Dussauge

contents

prologue
MRI's heyday

Sweden, December 10, 2003 (Concert Hall, Stockholm). Professor Hans Ringertz, Chairman of the Nobel Assembly, declares:

> Professor Lauterbur and Professor Mansfield,
>
> Your discoveries of imaging with magnetic resonance have played a seminal role in the development of one of the most useful imaging modalities in medicine today. All indications are that it will be even more important in the future of both medical practice and research, and, above all for the patient.
>
> On behalf of the Nobel Assembly at Karolinska Institutet, I wish to convey to you our warmest congratulations, and I now ask you to step forward to receive the Nobel Prize from the hands of His Majesty the King. [1]

On October 6, 2003, the researchers Paul Lauterbur and Peter Mansfield were awarded the Nobel Prize in Physiology or Medicine for their contribution to the early development of MRI (Magnetic Resonance Imaging) in the 1970s.

That MRI was found worthy of a Nobel Prize is less striking than what was considered exceptional about its development: What earned MRI and its developers a scientific and cultural consecration was that they turned a quantitative measurement method, producing data and curves from small chemical samples, into *an imaging technology*, bringing out pictures of the inner body on display on a screen.

In his Presentation Speech, Chairman of the Nobel Assembly Hans Ringertz insisted on the immeasurable value of images as such:

> Using a metaphor, magnetic resonance spectroscopy [the measurement technology behind MR imaging] is like listening to a radio broadcast of a symphony in the 1940s. Imaging [i.e., MRI] would then be like sitting in a concert hall listening to the symphony, and not only hearing but also seeing the instruments, how they play and where they are located, like organs in the human body. And when you hear the violins, you can even recognise, as in a magnetic resonance image, a false note like a disease process in that body.[2]

Imaging opened up a whole new dimension in diagnosis. But to *see* into the inner body with the help of technology is not an exclusive feature of MRI; much wider than this, technological vision has become an integral part of Western medicine—and of our culture—as Ringertz insisted: "To be able to visualize the inner organs of humans without invasive techniques is of paramount importance to modern medicine." [3]

The extent of the use of MRI in the world (approximately 22 000 MRI scanners in 2002, performing more than 60 million MRI examinations) gives an idea of how widespread the practice of costly and complex imaging of the body is today.[4] Further, the crucial importance of imaging for the outcome of health care ("an invaluable aid in the whole healthcare chain," Ringertz says) implies that deliberately choosing not to conduct examinations with imaging technologies like MRI would not only be counterproductive—it would be immoral.[5] By 2003, *MRI seeing* into the inner body was therefore not just an option any more. Seeing with MRI had become a possibility that could no longer be excluded, i.e. a moral and cultural obligation—part of an imaging imperative in Western medicine and culture.

Why image the inner body to such an extent when most Western governments attempt to contain health care costs and to control the consumption of high-technological medicine? The extensive practice of medical imaging is a sign and a part of the Western cultural utopia of the *transparent body*. Corporeal transparency as an ideal stands for specific but far-reaching forms of bodily intervention enabled by technological progress—a fundamental modernist utopia of Western science. MRI images, like other technological images of the inner body, reflect the utopia that technology enables medicine and culture to pierce, and eventually to modify, the secrets of "nature".[6]

The history of MRI that this dissertation proposes is therefore that of a construction of corporeal transparency, a history of the utopia of technomedical vision as knowledge and control.

The attribution of the Nobel Prize to two developers of MRI was thus not simply the recognition of even groundbreaking scientific work: In 2003, MRI was consecrated as an icon of our times' technological power to make the body transparent—and of our cultural craving for it.

[1] introduction

BACKGROUND AND PROBLEM: BLIND TECHNOLOGIES OF SEEING

The attribution to MRI of the Nobel Prize 2003 in Physiology or Medicine marked a symbolic consecration of modern medicine's radiological powers of vision into the human body. A search for "diagnostic radiology" in the *Encyclopedia Britannica* today takes the reader to "diagnostic imaging", with the following definition suggesting that radiology has come to embody a generic mode of vision: "*also called Medical Imaging*, the use of electromagnetic radiation to produce images of internal structures of the human body for the purpose of accurate diagnosis." [1]

Radiology appears as the medical art of seeing with blind technologies—technologies of the invisible. Whereas light was long the main medium by which the body could be viewed—with the anatomist's eye, or through the disciplining mechanisms of microscopy and photography—Roentgen's discovery of X rays in 1895 opened a new visual era in medicine in which non-optical, invisible physical entities have been used to produce vision. Since X rays became a part of both our visual culture and our medical understanding of the body in the first decades of the twentieth century, several other medical technologies have been developed which have enabled the creation of different kinds of images of the inner body. These technologies mobilized a range of physical phenomena such as ultrasound or gamma radiations—to mention but the best-known examples—to penetrate and image the inner body's hidden depths. None of these phenomena were based on visible light as the microscope, photography and film had been. Instead, it was invisible entities such as electromagnetic radiations and acoustic waves that were mobilized to produce visible pictures.

MRI is itself based on the stimulation of protons (also called hydrogen nuclei, i.e. the "core" of hydrogen atoms) with radiofrequency waves in a magnetic environment and on the subsequent reception of the protons' response signal. Seeing with MRI thus means by and large seeing with protons—to draw a parallel with Edward Yoxen's phrase "seeing with sound" about the development of ultrasound imaging.[2] To say that MRI enables seeing with protons or that ultrasounds enable seeing with sound is to emphasize the constructed character of medical images, and to acknowledge the mediation that constitutes radiological vision. MRI is then one example of radiology's constructed apparatus of vision—consecrated as such in 2003.

The production of visual displays (or "scans") with MRI implies that users and developers deploy advanced efforts to make MRI's electromagnetic waves and fields bring out invisible aspects of the body as visible on a screen. Although the above may be said of any radiological technology, this was explicitly stated about MRI in its early days. For instance, comparing MRI ("NMR scanning") to its predecessor as big-ticket scanner, X ray computed tomography (CT), US psychiatrist and neuroradiologist William Oldendorf said in a lecture in 1985:

> *CT scanning is to NMR scanning as the game of checkers is to the game of chess. And if you know checkers, it's a very simple game with almost no moves that are possible, so you can't develop any elaborate strategies. But chess has many moves which allow for very elaborate strategies to be developed. So CT with its two possible tissue interactions with X rays allows for very simple strategies whereas, as we will see, the interaction of*

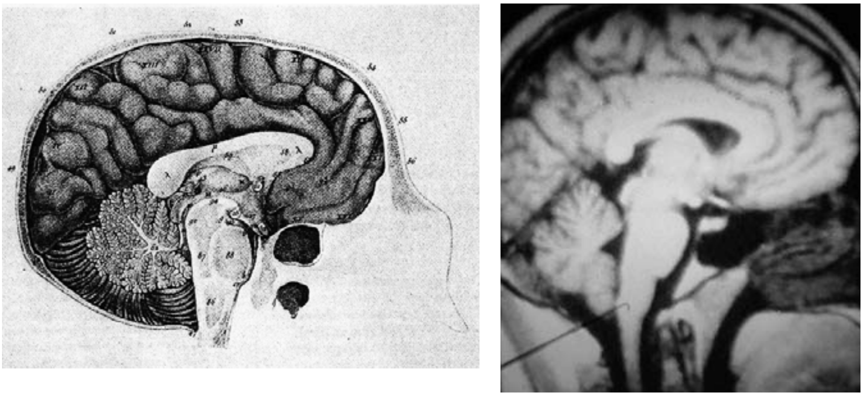


Figure 1. Early 19th-century anatomic depiction of the brain by Franz Joseph Gall (left) and 1980s MRI scan of the brain (right).[4]

> *magnetic fields with tissues is so elaborate that it allows for very elaborate strategies and has an enormous potential.*[3]

What Oldendorf was referring to was that in the very *use* and further design of MRI, researchers and clinicians had to repeatedly face a range of technological choices. This explicit open-endedness—or fundamental instability—of what could be made visible by human intervention makes MRI a good object of study to shed light upon the constructed character of technomedical vision and production of the body.

STS (Science and Technology Studies) scholars Olga Amsterdamska and Anja Hiddinga have observed that "[s]ome of the visual representations of disease produced by modern technologies, such as ultrasound echography, computed tomography (CT), magnetic resonance imaging (MRI) [...], can be seen as direct continuations of the anatomical tradition in medicine".[5] Truly enough, if we consider the two pictures displayed as Figure 1: on the left, phrenologist Franz Joseph Gall's manual anatomical depiction of the brain in the early 19th century, and on the right, an MRI scan of the brain from the 1980s. The difference between Gall's depiction and the MRI scan seems minimal in spite of the almost two hundred years that separate them.

The resemblance between Gall's depiction and the 1980s MRI scan is all the more striking if we contrast them with the earlier, 16th-century anatomic depictions of the brain shown on Figure 2. For instance, a striking difference is that what is called brain convolutions (the "sausage-like" shapes of the brain visible both in Gall's picture and in the MRI scan in Figure 1), today inseparable from our notions of the brain and brain function, were not represented in Vesalius' major anatomic work *De humani corporis fabrica* (Figure 2). Instead, the emphasis in both the 16th-

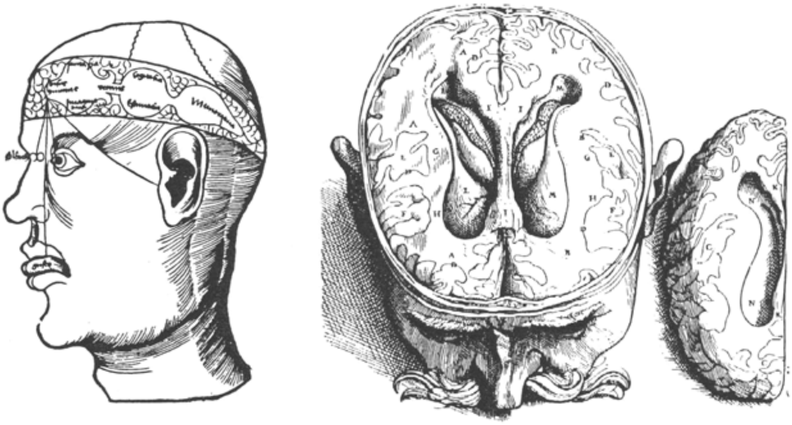


Figure 2. Early modern anatomic depictions of the brain. Left: Gregor Reich's portrayal of the Cell Doctrine in which functional properties of the brain are attributed to the brain's ventricles (cavities), 1503. Right: One of Vesalius' depictions of the brain in his major anatomic work *De humani corporis fabrica* (1543), with emphasis on the ventricles.[6]

century images reproduced here was placed on the ventricles "which, in keeping with the ancient Greek idea, were the reservoirs of the animal spirits responsible for sensory and motor activity of the body".[7] Which is fully consistent with the fact that theories such as the Cell Doctrine emphasized the brain's cavities as repositories of the mind and of the brain's functional properties. Convolutions were therefore rather rarely depicted until the early 19th century, when the idea gained legitimacy that convolutions might be crucial to brain function, i.e. that the mechanisms of thought originated in these specific parts of the solid brain.[8]

Anatomy commonly refers to the "identification and description of the body structures of living things".[9] Historically, anatomical depictions were performed manually, and since the early modern period they had been based on the anatomist's dissections and the observation of corpses. Anatomy is a strong frame within which medicine's contemporary visual culture has grown. Art historians and medical historians have also shown that anatomy is a historically and culturally changing discourse on the body.[10]

The similarity of the 1980s MRI scan and Gall's 19th-century depiction leads one to wonder what the novelty of MRI consisted in, and how the posited open-endedness of MRI became aligned with anatomy's material visuality. These examples raise the question of the historical continuity of medical frames of understanding of the body, not least that of anatomy.

Moreover, MRI was introduced, appropriated and developed by actors belonging to different medical and scientific professions. Controversies as to *who* was able to understand what the new pictures showed soon emerged, as biologists questioned the legitimacy of radiologists—the specialists of technified anatomical images. At stake here were the medical-scientific traditions in which MRI was inscribed: Were MRI representations inherently visual, anatomical images to be handled by radiologists, or were they the bearers of chemical/microscopic information that biologists, chemists and pathologists would be best able to produce and interpret in a continuation of their laboratory methods?[11]

Olga Amsterdamska and Anja Hiddinga have argued that the relationship between specialization and technification in the twentieth century is important—although poorly understood—because it has articulated a fragmentation of the body along different and often incompatible medical perspectives. Amsterdamska and Hiddinga address how, on the one hand, clinical medicine that relies on an anatomical tradition and, on the other, laboratory science, took part in "the proliferation of ways of analyzing the body and the dispersal of analysis among laboratories and specialists."[12]

The introduction of MRI in a medical world functioning as a fragmented set of subcultures hardly communicating with each other contrasts strongly with Amsterdamska and Hiddinga's assertion that MRI was developed in a straightforward continuation of the anatomical tradition. If there is a supremacy of anatomy's visuality in medicine, it is thus one that must be understood as reproduced in the development of technomedical practice and representations, for instance with MRI; understanding how is one of the tasks of this dissertation.

purpose & questions

MRI stemmed from a blind measurement technology which was further developed in research and practice to enable seeing into the inner body. Vision with MRI was open-ended; and it was to be developed and tamed in a context of fragmented medical perspectives on the body and on technology. Still, it seems that MRI was shaped in the continuity of anatomy's vision. My main purpose is to explore how vision with MRI has been constructed in practice in relation to medicine's existing ways of knowing the body.

My main questions are therefore: What were the initial conditions for the establishment of different kinds of MRI research in early-1980s Sweden? How was vision with MRI shaped in relation to medicine's existing practices and ways of seeing? How did divergent understandings of MRI reproduce or challenge anatomy's dominance in practice?

RESEARCH LANDSCAPE: MRI AND ITS RADIOLOGICAL VISION

Whereas the establishment and development of X rays and early radiology has been studied rather extensively with perspectives from the fields of history of technology and cultural history, the scholarly history of more recent medical imaging technologies is scarce.[13] Sociologist Stuart Blume and historian Bettyan Holtzmann Kevles have each written a scholarly history of MRI as part of a broader history of medical imaging technologies.[14] In science and technology studies (STS), MRI has been the subject of several sociological inquiries in the late 1990s and early 2000s. Here I first present and discuss Blume and Holtzmann Kevles' two accounts of the history of MRI, and then introduce the perspectives from STS studies of MRI that will be useful in the present study.

MRI's early development: historical perspectives

Blume and Holtzmann Kevles both locate MRI's roots in the quantitative measurement technology called nuclear magnetic resonance (NMR), which was commercially available and became a widely used equipment in chemical laboratories in the late 1950s and onwards. NMR was based on the property of certain atomic nuclei of absorbing specific energy from radiofrequency waves when placed in a magnetic field, and of re-emitting a signal when returning to equilibrium; the latter process was termed "relaxation". The shape of the nuclei's relaxation signals provided information about the molecular environment of the atoms: the possible molecules of which they were a part, and the interactions with the molecules that surrounded them.[15]

Until today the object of magnetic resonance studies of human tissues has been predominantly the hydrogen nuclei (protons) of the water molecules, by far the most common molecules of the body. Early among the 1950s NMR studies of biological tissues were the Swedish researchers Erik Odeblad and Gunnar Lindström, who showed in 1955 that "proton magnetic resonance signals may readily be obtained from living cells and other biologic tissues." Odeblad and Lindström suggested that proton-NMR properties of the tissues differed depending on their amount of water, as well as on the kind of molecular structures in which protons are bound, for instance fat or non-fat tissue.[16]

From there, and not least in the shadow of the Nobel Prize 2003, controversies have taken place about who should be given the main credit for the invention of magnetic resonance imaging.[17] However, a physician working in biophysics in New York, Raymond Damadian, is generally credited with taking the first steps towards a spatialization of NMR signals for analysis of bodily tissues *in vivo* (i.e., in the living body) in the 1960s and early 1970s. Drawing on his experimental research on rats, Damadian shared the view that cancer cells had a different water structure from healthy cells and conceived of an NMR scanner as a *cancer detector*: a device that would be able to answer the question "is there a cancer in a given place of the body?" on the basis of protons' relaxation properties. An NMR-based cancer detector would enable both the identification and the classification of tumors. Damadian filed a patent on the principles for such a device in 1972 and created his own company in the late 1970s, FONAR, with the purpose of developing commercial NMR scanners. Blume argues that Damadian viewed NMR scanning as a tool for the pathological laboratory.[18]

Damadian's publication of an article in *Science* in 1971 about the relaxation properties of cancer cells gave rise to both skepticism and interest in biophysics, NMR research and adjacent fields, and triggered research by several physicists and chemists in the 1970s.[19] A chemist at the State University of New York, Paul Lauterbur, developed a method to spatialize NMR signals further (i.e. to be able to control and identify where, spatially, protons' NMR signals came from), for the purpose of developing an imaging technology that would provide a map of proton density in an object or body part. Lauterbur imagined that the magnetic fields at work in NMR could be configured to create a physical space where each point would have different resonance properties, and could therefore be localized. Using magnetic gradients (spatial distributions of magnetic fields) and a mathematical "back-projection technique" of reconstruction of images, Lauterbur constructed a spatial map of the density of protons in test objects in 1973. NMR imaging did not provide as detailed chemical information as quantitative measurements with NMR. Instead it provided an image of one characteristic, the density of protons in different parts of the object imaged. The test picture published by Lauterbur showed a cross-section of two test tubes filled with regular water, the intensity (roughly, color) of which on the NMR scan was clearly distinguishable from their surroundings filled with another chemical compound. With this method, NMR no longer handled only isolated samples (as in NMR devices for chemical analysis) or a single focused point in the body (as in Damadian's original plans for a cancer detector), but instead "saw" a whole spatial world made of planes and volumes.[20]

Other research groups undertook to develop a technology for NMR scanning of the human body in the 1970s. According to Blume, these groups pursued two different goals in MRI's "exploratory phase" (1973-

1977): either cancer detection and tissue characterization, i.e. a device for pathological laboratories, or imaging technique as such, i.e. a device for radiological practice. Work focusing on pathology detection emphasized the importance of protons' *relaxation times* (called T1 and T2) as a source of information about bodily tissues, whereas developments aiming at developing a "generic imaging modality" focused on methods to spatialize and contrast the strength of NMR signals better (this "strength" reflected mostly proton density), e.g. methods minimizing the amount of data processing.[21]

Blume points out that "[w]hat characterizes the exploratory period of magnetic resonance imaging is the gradual incorporation of medical goals into research initially rooted in physics (and in some cases in chemistry)." Soon most NMR-imaging research groups began to build connections with the medical world, and defined and worked at clinical problems such as shortening the examination time, i.e. the time needed to scan a patient with NMR imaging. As NMR images of body parts were successfully produced and published, medical collaborations became crucial when "anatomical drawings or other means of validating NMR images" became necessary in the second half of the 1970s, and when clinical experience became a critical factor in the competition between NMR-imaging groups. By the end of the 1970s, industrial interest had emerged from radiological equipment companies that had been involved in developing and selling computed tomography (CT), and the equipment costs (powerful and precise magnets) for research groups aiming at whole-body imaging made industrial collaboration necessary.[22]

Blume emphasizes that the development of NMR imaging was profoundly marked by the uncertainties about what the medical purpose of the technology was to be, who it was to be used by, and what for: Did only pathologists and biologists have the competence to produce and interpret NMR-imaging signals about the status of bodily tissues? Or were rather radiologists to be interested in the new images and competent to design and interpret them? Among others, a prominent NMR-imaging researcher in the cancer-detection trend, John Mallard, argued strongly in the early 1980s that radiology's usual method of exploring new kinds of images—comparing them to images obtained with established technologies—was inadequate. Instead, he argued, it had to be "through *biological research* that both uses and interpretation of images was to be pursued." However, Blume shows that radiologists' interest was awakened by the early 1980s and that the first commercial versions of NMR scanners were primarily marketed towards them, not least due to the radiological equipment manufacturers' established contact base with them.[23]

The NMR-imaging technologies developed by competing groups differed in terms of signal measurement technique, which included hardware such as type of magnet and coils, but also, and most importantly, the software part of MRI in the form of *imaging sequences* (also called *pulse sequences*), which determined which type of image was generated. Pulse sequences were the profiles of the radio wave signal sent to the sample or body to stimulate protons, thus creating information, and to measure returning signals, therefore determining whether the pixels in the image created would be weighted mostly with proton density or relaxation properties. Different pulse sequences would generate different pictures, in which certain bodily structures were more visible than others (cf. Figure 8 in Chapter 3). For instance, T1-weighted images were in focus for the researchers pursuing goals of cancer identification and characterization. Blume views this instability of NMR imaging as a competition between different problematizations or purposes, embedded within which were central technomedical choices in the design, use and interpretation of NMR-imaging technology.[24]

Blume's history of MRI stresses economic constraints on technological development, and, not least, on the market possibilities for MRI. Holtzmann Kevles also situates MRI in the context of the strict regulations imposed on costly medical equipment that had been formulated and implemented by the USA authorities to prevent an unrestrained diffusion of CT in health care. Developed a few years after the introduction and subsequent regulation of CT, MRI was likely to be affected.[25] Economic and regulatory aspects in Sweden will be treated where relevant in the following chapters.

In contrast to the uncertainties that Blume emphasizes, Holtzmann Kevles treats the history of MRI as a quite uncontroversial development towards radiological images and deals uncritically with (then) contemporary radiological uses of the technology—i.e. what it made possible to "show" in the mid-1990s.[26] In a recent critical re-reading of the early development of MRI, sociologist Kelly Joyce argues that

> [t]he medical imaging innovation literature taken as a whole shows how successful representational strategies and techniques emerge from multiple possibilities and social interactions. Access to resources, professional authority, and institutional relations all influence innovation outcomes, co-constituting the artefact developed. Yet, while earlier work illuminates how innovation is a social (and not a predetermined or inevitable) process, it does not delve into the relationship between the development of a particular technology and the contemporary emphasis on images and visuality. [---] The lack of attention to particular forms of culture is also found in broader theories of technological innovation.[27]

In my view, Blume and Holtzmann Kevles leave out several important aspects (partly because of the periods they focus on, and partly because of the theoretical perspectives they draw on): How the ways of using MRI and seeing with MRI were shaped *in practice*; how MRI's visuality operated in relation to non-visual knowledge; and what happened with other types of MRI representations (measurements, representations of bodily flows, motion, and molecular interactions). In other words, Blume and Holtzmann Kevles ignore MRI's interaction with medicine's different material cultures of practice, and hence they fail to provide an account of whether and how MRI as a technology was aligned with existing practices of knowledge-making and representation, and its relation to radiology's clinical vision.

Joyce identifies two central issues in the scanty historiography of MRI: first, why and how MRI "turned visual" is important but still unexplored; second, how MRI representations have been the site of negotiations between scientific, medical and popular cultures (which is illustrated, among others, by MRI's disturbing resistance to being historically categorized as a quantitative or visual method).[28]

MRI's radiological vision: STS perspectives

Whereas scholarly historical work on MRI ends in time where this thesis begins—in the 1980s—sociologists within the STS-field (Science and Technology Studies) have recently conceptualized the way MRI visuality operates more recently, i.e. in the late 1990s and early 2000s.[29] Their studies are useful to me because they help characterize what has now become MRI's dominant functionality: its radiological vision. Further, I share the theoretical premise of much STS work on medical imaging: that visual representations *produce* the body rather than merely depict it (which notion of the body is at stake here is treated in the next section). I shall here outline a few main features of two STS studies relevant for this dissertation; their implications will be developed in due course in the following chapters.

Sociologist Amit Prasad provides useful tools to characterize and understand how MRI visuality operates in clinical radiological practice. In a 2005 publication, Prasad has argued that because of the multiple designs of MR images through pulse sequences, MRI enacts a "cyborg visuality" (after Donna Haraway's notion of the cyborg): a perspectival, partial, and situated construction of reality.[30] Prasad also shows that MRI's visuality otherwise functions like radiology's: it is *bifocal* (it isolates bodily parts but always re-situates them in the whole body), which requires the body to be handled in practice as notational (organized in separable parts and consisting of visual and non-visual, e.g. textual, information).[31] The MRI visuality Prasad characterizes is the most commonly used nowadays, i.e. radiological visuality, based on bodily anatomy and used for diagnostic purposes. This dissertation will show that other MRI visualities were envisaged, developed and used in the 1980s; I will also discuss how they related to radiological vision.

Kelly Joyce has studied other aspects of MRI's radiological vision in a study of popular and professional narratives on MRI images. She explores how the visuality of anatomical MRI is made authoritative and the consequences of this for knowledge and patients. Joyce shows that the erasure of human intervention is a common trope in popular narratives as well as in MRI radiologists' discourses, which equates the image with the body and gives the MR image its authoritative character. She also argues that the human intervention in the practice of MRI and in examination choices etches together economic, regulatory and epistemic aspects.[32] The context of Joyce's study is US-American, which makes it difficult to simply import her analyses to a Swedish context in which health care is publicly funded, and where decisions about examinations and patients are structured by other policies and practices. However, I will retain from her study the observation that the narrative erasure of human intervention is a source of MRI images' authoritative character.

THEORETICAL PREMISES: TECHNOMEDICAL GAZES

In order to account for the "ways of seeing" built into MRI and its practices I use the concept of *gaze* in a specific way that I shall briefly present here.

gazes

In *The Birth of the Clinic* (*Naissance de la Clinique*, 1963), philosopher Michel Foucault coined the concept of "medical gaze" (*regard médical*) and, more precisely, spoke of an "anatomo-clinical gaze" (*regard anatomo-clinique*). Foucault's anatomo-clinical gaze refers to the mode of knowledge established in modern (late 18th century/early 19th century) medicine—a way of knowing that was essentially visual and saw the material bodily structures of the dissected corpses as primarily constitutive of clinical medical knowledge about diseases.[33] Historian of medicine David Armstrong reminds us that Foucault's notion of medical gaze also encompassed "the way medicine has perceived things, the way things have looked or seemed".[34]

As Swedish art historian Torsten Weimarck describes it, Foucault's major contribution was to inquire into "reality's own historical gestalts, the forms in which *what is real* appears."[35] Foucault showed—Weimarck argues—that after the Renaissance's interest in the visual, it is during the 18th century that medical rationality made visual perception its predominant mode of truth. Further, Weimarck explains that the construct known as the anatomical body became a naturalized object; he writes:

> The natural sciences' *anatomical body* is a historical construction of a very special rationality, related in different ways to an emergent scientific philosophy of power. Anatomy does not naturally exist in our bodies. The anatomic body appears as an embodied truth, an image that presents itself as self-explaining. But the anatomic language demands a specific apparatus to be intelligible and to be fluently read and written; [...] so that today, without being aware of it, we often observe bodies in our surroundings, including our own body, with anatomy's concrete, appearance-focused and critically examining gaze. [36]

Analyzing the practice of early modern anatomy, Weimarck explains further that anatomy decomposed the "natural object" (the corpse's flesh) into parts and then reconstituted it—"*but now in another way*, by transforming them [parts] into an anatomical object by means of a special code, where the object of knowledge and the natural object are collapsed in each other. And in this, the marks of the [anatomical] process have been cleaned up, and it is as if one was in front of *reality itself*." [37]

Foucault has also contended that in the 18th century's integration of the practices of anatomy in those of the clinic, anatomy's spatial organization of the body (its material visuality) merged with the clinic's conception of time: the timeline of illness events as narrated by the patient and as observed by the doctor. As a result, the new clinical-anatomical time was the time that pathologies took to leave now anatomically observable marks in the body; it connected two previously separate ways of conceiving disease: through its geography (anatomical gaze) and its history (clinical gaze).[38]

The notion of gaze as originally deployed by Foucault, and as I will use it here, is thus not inherently visual and refers instead to the structures of what it is possible to conceive and to know, what this implies about subject/object positions, and how subject and object of knowledge mutually construct or discipline one another. The transformation leading to the emergence of the anatomo-clinical gaze bore on fundamental aspects of knowledge: on which kinds of objects were defined as accessible to human medical knowledge, "on the grid that makes it [this type of object] appear", "on the instrumental mediations that enables" the subject "to grasp" these objects; "on the forms of conceptualizations" that must be used, on ways of knowing and on the subject positions the clinician/physician would have to occupy to be able to perceive these objects of knowledge.[39] Visuality became a dominant mode of truth in 18th-century medicine and is, however persistent, but one historical form of truth.

As media scholar Lisa Cartwright re-asserts, another thing is clear in Foucault's *Birth of the Clinic*: Different gazes have co-existed, and co-exist, in medical practice. For instance, laboratory medicine with its instruments and its microscopic, invisible objects of knowledge performed what she calls a "chemical gaze" (which I will rather refer to as a *laboratory gaze* in this study), which "while not precisely that of the laboratory scientist alone, is not wholly congruent with the clinician's gaze."[40] These gazes mobilized different methods, instruments, and most importantly, different conceptualizations of the body and of disease and their epistemologies.

Other gazes that will play a role in the present history of MRI are *psychiatry's neurological gaze*, which the works of anthropologists Joseph Dumit and Anne Beaulieu will help me analyze in Chapters 4 and 5; and a *physiological gaze*, aspects of which Cartwright has studied in *Screening the Body* (cf. Chapter 6 in this dissertation).[41]

Finally: Where others have insisted on the ways gazes are constitutive of professional cultures, I have chosen to focus on gazes in particular rather than on the social groups in which they are embedded, so as to emphasize the *content* and the stakes of, in part, professional struggles.[42] The tensions and oppositions between professions rather point at something more fundamental: the multiplicity of meanings of MRI's technological apparatus and the broader cultural frames of understanding of the body that let these meanings emerge and evolve. I will therefore subordinate professional tensions to the interpretation of MRI's configurations of meanings and to the notion of gaze, and I will view a possible competition between professions (as staged by Blume as a competition for influence or markets) as an indicator of a competition between co-existing gazes.[43]

digital radiological media

MRI is a computerized medium producing data sets and images through the processing of physical data. In that sense, MRI representations have been created as digital images since the initial developments of MRI in the 1970s. In *The Reconfigured Eye,* media theorist William J. Mitchell has argued that the development of digital technologies has re-cast the "rules of the game" of the optical production of images. Relevant to the history of MRI is Mitchell's argument that the increased presence of the observer's choices in the very *production* of a digital image has introduced new elements of human intervention in the relation between a "referent" (what is imaged) and the picture of it.[44]

Whereas Mitchell insists on photography in *The Reconfigured Eye*, Anne Beaulieu approaches more specifically the importance of the digital in contemporary radiological technologies. Drawing on the work of Michael Lynch, Beaulieu explains that "digitalism" is a specific mode of visuality, different from "opticism". She contends that digital media enable (and are dependent on) new modes of production, handling/comparison and circulation of data. Beaulieu argues, among other things, that the "constitution of brain atlases" (i.e. of standardized sets of images of the normal brain) with digital technologies "relies on a particular version of what makes an inscription objective." In other words, digital media open the way for new configurations of objectivity that have an impact on medical definitions of the normal.[45]

The production of anatomical atlases with computerized radiological technologies (primarily CT and MRI), mostly in the 1980s and 1990s, is often referred to as "digital anatomy". Recent studies of digital anatomy have demonstrated that the specificity of digital media must be taken seriously, among other reasons because it has crucial consequences for the ways the body is produced, manipulated, reproduced and circulated—and therefore, for conceptions of bodily space, life and bodily time.[46]

technomedical gazes and bodies

The notion of body implied in this study is traditional in medical (intellectual) history: body means here medicine's objective body taken as a cultural and historical construct.[47] Medical anthropologist Joseph Dumit situates this stance:

> Within other medical anthropologies [than phenomenologically inspired, clinical medical anthropologies], some sociologies of medicine, and the history of science and medicine, a different approach is taken. Instead of the experience of health and illness as variable, the "objective body" is taken as culturally and historically contingent. The body is understood as the object of a scientific and medical gaze that changes with the times, the discipline, site, culture and circumstances. These approaches understand the objective body to vary with the development [...] of technoscientific culture, attending to how the historical-cultural category of the person (via politics, economics, etc.) influences the evaluation of the objective body.[48]

Therefore, my purpose is not to follow a "hermeneutics of suspicion" and disclose medicine's objectivity as highly cultural and historically contingent.[49] Rather, I shall explore the objective body as the cultural-historical construct that medicine has as its "working object," to borrow a term from Lorraine Daston and Peter Galison, and I will consider how this working object works in practice.[50]

The gazes introduced above relate to different medical practices, primarily: anatomy/radiology, and laboratory medicine. In a similar way, I will use "MRI gaze" to refer to the vision enabled and performed with MRI. A gaze-informed re-reading of Blume's early history of MRI suggests that the early MRI gaze was shaped in the USA and the UK along two distinct lines: an anatomical radiological gaze and a laboratory gaze. The main purpose of this work may also be reformulated: to investigate empirically whether the MRI gaze has been aligned with existing gazes, and how.

The gazes introduced above were highly intertwined with the technological means used and designed to enact them.[51] Similarly, the MRI gaze does not refer only to divergent theories of the body; rather, the MRI gaze was a multiple system of knowledge at the crossroads of technomedicine's cultures of seeing, professional epistemologies of technology and of the body, and political economies of health care. The MRI gaze therefore structured highly material practices which set in relation bodies, technology, and observers. By focusing on differing practices of MRI, the present study offers a window on how medicine's divergent gazes have interacted in technomedical practice.[52]

In order to explain how Swedish actors *in practice* shaped the MRI gaze in relation to existing gazes and modes of knowledge, I also use Amid Prasad's notion of *cross-referential network*. The notion of cross-referencing assumes that radiological representations/configurations of the body (e.g. with MRI) have highly unstable meanings. The concept itself refers to the systematic comparison of MRI representations with established medical facts and representations of the body in order to stabilize the interpretation of MRI scans. The facts and technologies mobilized in the cross-referential network thus frame the meaning of MR images, and thereby, the local developments of MRI gazes.[53]

In order to understand the material visualities at stake in MRI and the complex relations between observers (researchers/clinicians) and MRI technology, I take inspiration from Lisa Cartwright's interpretations of how visuality was configured in microscopic culture in the nineteenth century. In a Foucauldian tradition, Cartwright has shown how early microscopists as observers deployed a disciplinary apparatus to both control technology and shape microscopic objects to adapt them to the observer's means of study. Cartwright also shows that microscopy's visuality was characterized by a blurring of object/subject positions, and that the endowing of light with a form of agency (capable of compromising representations, and therefore to be controlled) was constitutive of microscopy's visual culture.

Finally, Cartwright demonstrates that the shaping of microscopy's visual and technological culture was tightly intertwined with the microscopists' construction of their object of study: an emergent biological concept of life.[54]

METHODS

The background I have outlined in the two main sections above is that of a fragmented medicine with its divergent gazes producing partly incompatible bodies, and, outside Sweden, groups of NMR/MRI researchers with divergent understandings of MRI. The purpose, questions and perspectives presented above imply that my empirical focus is double: First, I am concerned with how early Swedish MRI researchers have acted on MRI and from which motives. Not least, *researchers' understandings of what MRI could do* (or should be made to do) will help me contextualize the shaping of the MRI gaze (although they are insufficient, on their own, to *explain* the latter). Second, this study focuses to a large extent on *material, technomedical practices: of MRI, of images, and of the body*. This implies that large parts of this dissertation are close readings of technoscientific/ medical work, as exemplified by selected articles published by the MRI researchers.

In terms of methods, I am concerned with two main issues which I shall outline here: First, I want to do justice to the situatedness of the histories and meanings of MRI. Second, dealing with actors and sheer amounts of highly cryptic material requires methodological strategies specific to the history of contemporary science, medicine and technology.

histories and definitions of MRI

The divergence of understandings about what MRI was must be taken seriously: it is not simply an empirical fact (cf. Blume), but also a central methodological premise. In the first chapter of his study of the brain-imaging technology called positron emission tomography (PET), Joseph Dumit states that "PET's history is interior to its definitions."[55] Later he develops this stance:

> To compile a history of PET, then, one must first come to terms with the definition of PET. [---] At first glance, these seem like moot questions: PET is simply a set of techniques and technologies that permit in vivo functional imaging with positron-emitting nucleides. But as I shall show, this general definition satisfies no one; it explains neither PET's place in the worlds of science and medicine nor its limits. Rather, there are many concurrent,

> competing definitions of PET, each with not only ontological and teleological but moral and practical consequences as well.[56]

Dumit's point is that different meanings of PET coexist, and cannot be explained with theories that emphasize either some dominant, agreed-on understandings of a phenomenon or device (e.g. Thomas Kuhn's notion of paradigm) or the "agonistic struggle between scientists who compete by amassing more powerful allies than anyone else" (as in some studies based on actor-network theory). Instead, Dumit attends to scientists' "contested narratives", handling them as "ethnohistories, perspective-dependent accounts told within a contested field".[57]

This approach enables Dumit to get at a few crucial aspects of the instability of the meanings of PET which he is then able to unpack in the different contexts of the production and use of PET images (e.g. laboratories, courts, magazines, psychiatric practice). To put it plainly, the different histories of PET "matter for what PET is, for how it is practiced, and for what kinds of meanings are produced through it".[58]

The historical landscape of MRI is in many ways similar to PET's. As Chapter 2 will hint at, and Chapters 3 to 6 will follow, the Swedish actors involved in the early use and further development of MRI had divergent notions of what MRI was, of what the MRI gaze ought to be used for in practice and how. None of these histories and practices can be said to have simply dominated the others in time.

In order to obtain access to those stories and to actors' understandings of MRI, I have interviewed selected actors in the Swedish history of MRI. Not all are represented, and I have made the choice to have in-depth contact with a few research groups rather than attempting to gather an unmanageable amount of narratives across all MRI communities. The three groups of MRI researchers I have focused on were based at Uppsala University Hospital, St. Göran's Hospital (Stockholm), and Lund University Hospital.[59]

In other words, this study is by no means an all-encompassing history of MRI. In line with Dumit's approach, I have used informants' narratives to get at a few culturally available definitions of MRI. To some extent, I focus more on the contents and implications of these understandings of MRI than on the actors' subjectivities. My purpose is never to psychologize these narratives or to give explanations of actors' behavior and decisions. Whenever such explanations are given, they are a reproduction of the actors' own making sense of their decisions and actions.

Rather than giving them an explanatory power, I have interpreted my informants' narratives with respect to the following: first, as a way to emphasize the situated historical specificity of the meanings and practices of MRI, second, to make sense of the actors' scientific or clinical work in their development of an MRI gaze, and third, to identify the tensions between divergent productions of meaning with MRI.

oral history and evidence

Writing the history of contemporary science, medicine and technology is attended by a number of difficulties that require specific strategies. The issues encountered in the present study are not unique, I refer the reader to other works on the topic for general reflections and theoretizations.[60] Here I focus concretely on the sources I have used and sometimes co-produced in this work.

The interviews I have conducted can be characterized as exploratory and semi-structured.[61] The purpose of the interviews has been, first, to let actors thematize their history of MRI; second, to map relevant actors, events, and further sources; and third, to identify MRI research projects for closer study.

Moreover, my informants have helped me understand the science/ technology/medicine they had been working with, which has enabled me to understand some fundamentals of the highly technified MRI gaze. This is no innocent information: it is, among other things, through their explanations of what they concretely did with MRI that I was able to identify definitions of MRI, and what possibly opposed these to each other.[62]

A second main kind of source used in this study is the scientific articles published by MRI researchers. First, I have browsed one Scandinavian radiology journal (*Acta Radiologica*) for all MRI content in the 1980s, and conducted a series of online searches in the U.S. National Library of Medicine's international database for medical publications (PubMed).[63] Second, I have used my informants' descriptions of their projects in our interviews, and in a few cases in their CVs and/or publication lists, as a tool to select the publications on which to base my analyses.[64]

In order to study early decisions made by the Medical Research Council on the introduction of MRI in Sweden, I have used archival material of the Swedish Research Council (*Vetenskapsrådets arkiv*) and non-archived project documents then kept at Uppsala University Hospital's radiology department and lent to me by Anders Hemmingsson. I have also used copies of official documents handed out to me by my main informant at Sankt Göran's Hospital, Lennart Wetterberg. The documents (and other evidence) lent to me by informants are referred to as contained in "private archives".

I have analyzed specific examples of MRI's public portrayal in Chapter 4, as depicted in a few radio and TV programs from the 1980s. These programs were searched for and accessed at the Swedish National Archive of Recorded Sound and Moving Images (*Statens Ljud- och Bildarkiv*) in Stockholm.

A few articles about MRI used in my analyses come from the general press. The press articles I refer to in the study have been mentioned to me by actors and are not the result of a systematic press search. In order to identify and study controversies about MRI in the medical community, and to construct a background picture of the debates about high-technological devices in Swedish health care in the 1980s, I have systematically browsed through the Swedish medical journal *Läkartidningen* (LT) for the years 1978 through 1990. *Läkartidningen* is the journal of the medical profession's union, the Swedish Medical Association (*Sveriges Läkarförbund*), and contains both debate articles, health care policy news, and scientific articles.

Two copies of local video recordings of lectures held in the 1980s have been passed to me by Lennart Wetterberg. I was lucky to have this opportunity to "observe" after the fact, and I have used them as regular evidence for the lectures concerned, assuming that these recordings had not been intentionally distorted in the copying process.

Finally, I make use of private videos posted on the multimedial Internet site YouTube (www.youtube.com) in Interludes 3 and 4. I have accessed these videos once and transcribed them with respect to what is said, shown and physically acted on them.

For the sake of transparency the appearance of quotations in this text varies according to the medium quoted:

> This smaller Corbel typeface I use for printed evidence (reports, articles, printed documents, publications, textual internet content etc.) and literature.
>
> *The Corbel italics typeface I use for primary and secondary oral sources. With primary sources I mean interviews conducted by me. Secondary sources may be interviews and comments performed in radio or TV programs, video recorded talks, self-recorded videos posted on the Internet.*

choices

In order to follow the shaping of the MRI gaze and MRI bodies, this study focuses primarily on MRI research groups. This dissertation builds to a large extent on microhistories: in-depth studies of selected research projects, conducted in local settings by sets of individual actors. Moreover, I have often framed parts of such studies with actors' situated historical narratives. In that sense, my analyses are specific to their object of study. However, the examples used in this work have been selected because they point at broader meanings and processes, and so will my interpretations. To borrow a word from historian of science Peter Galison, my objects of study work as "probes" rather than typical or generalizable cases—as Galison writes about his work on the subcultures of physics, it is important to distinguish "between the use of local history as typical and the more located and emblematic use invoked in this book."[65]

The research groups I have studied were based in Sweden. I have included their international cooperation and influences insofar as this study's MRI actors explicitly brought up those in interviews or publications. To focus on a national scene was a premise for this study, since the regulations, research funding and authorities, and to some extent the research communities involved in the history of MRI have been highly national and varied between countries.

There are a few reasons for having concentrated particularly on Swedish settings. First, some of these arguments are methodological: living in the same country, it was possible for me to travel to meet many of the actors, several times if needed, and to gather material. Second, I also believe that it is important to study technoscientific practice in a country with advanced research practice and no industrial MRI production. Concretely, what are generally considered major scientific and commercial advances in the development of MRI have not come into being in Sweden, but much scientific and technological work has been conducted here. I want to argue that studying local innovation work without clear links to industrial development is an important alternative to innovation studies like those of Blume and Holtzmann Kevles, who focus on pioneers and groundbreaking innovation work in the countries where MRI was industrially developed. Further, the classical "diffusion phase" of a technology tends to make scientists into mere consumers of technological devices. In contrast, I wanted to make visible and analyze the science-making and technological development work involved when research groups materially started with a commercial device and from there, produced, adapted and explored a new space of representations.[66]

Yet another argument for a Swedish study is that no Swedish history of recent radiology has been written, in contrast to the overwhelming amount of scholarly work produced on the contemporary history of Anglo-Saxon biomedicine. Consequently, I intended to produce the present study as an example of these possible Swedish histories. Mine is a very specific and rather narrow history—but I hope it can be valuable to other researchers addressing contemporary Swedish radiology or medical technologies from a historical perspective. An additional argument here is that Sweden, as in many other national contexts, has publicly funded health care services. It is critical to generate studies of such systems in which the issues and stakes are different from those depicted in US-American scholarship which is deeply informed by—and often rightly concerned with—the private regime of health care in the USA.

limits

A first limit in this dissertation lies within the MRI research community: not all research groups are represented. Instead I have chosen to conduct in-depth studies of a smaller selection of cases. A second limit is at the boundary between these groups and other social groups: other groups of actors have been included when made relevant by the researchers placed at the center of the study. For instance, the Medical Research Council (*Medicinska Forskningsrådet*, MFR) is represented in Chapter 2. In contrast, patients are not represented here, unless researchers made themselves into spokespersons for them in their interviews with me or in their scientific publications (cf. Chapter 4).

This dissertation has a limit in time, and deals specifically with the 1980s. By 1990-1991, all Swedish university hospitals had purchased an MRI device and smaller hospitals began to acquire own scanners, leading to a broader clinical use and another relation between MRI and clinical radiology.[67] Moreover, the early MRI research groups' role also changed at the beginning of the 1990s. A new generation of MRI researchers had been trained in the 1980s and thereafter deployed MRI research in new directions. Some of the early groups disappeared, whereas many of their members went on working with MRI in other institutions in the 1990s.

STRUCTURE OF THE THESIS

This dissertation falls into seven chapters, of which five empirical chapters constitute the main part of the book. After studying selected aspects of early visions and negotiations about MRI (Chapter 2), I unpack in Chapters 3 to 6 a multiplicity of MRI perspectives and practices in their interaction with situated technomedical/scientific practices: radiology, psychiatry and laboratory medicine.

Chapter 1 is a general introduction to this book, where I have presented the purpose of this study, the problem, and the main questions. I have also presented existing historical and STS research on MRI, the theoretical perspectives used in the dissertation, and central methodological aspects.

Chapter 2 "Under the control of authorities" sets the stage for many of the developments addressed in the dissertation. It outlines how Swedish researchers' different interests in MRI first arose, and explores the decisions made by research authorities in the early 1980s on the purchase of Sweden's first MRI scanner. Here I argue that the Swedish Medical Research Council was quick to control researchers' various intentions to work with MRI by financing a national evaluation of the technology in one sole location—Uppsala. I further contend that as a result of the Council's funding decisions, clinical radiology was defined as the professional "home" of MRI, whereas experimental work on MRI, although positively acknowledged, was marginalized. I finally outline the diffusion of MRI in the second half of the 1980s and argue that the control of MRI that seemed to have been established by 1984 did not in fact last. Chapter 2 thus studies some of the initial conditions for the shaping of the MRI gaze in Sweden.

In Chapter 3, "Going radiological", I examine how researchers made MRI radiological after the Medical Research Council's initial decisions. This chapter is organized thematically, as I study two different arenas for the production of meaning. First, I analyze the arguments formulated by MRI researchers in the course of the clinical evaluation of the technology and argue that MRI was dominantly defined as a "better" technology within the frame of existing radiological devices and representations. Second, I turn to the actual practices of the radiological MRI gaze and show how researchers made MRI "see" the body in accordance with the fundamental principles of radiology's anatomical gaze.

Chapter 4 is entitled "Seeing all our patients' brains" and explores how and with which consequences researchers integrated MRI in their clinical psychiatry practice at St. Göran's Hospital. Here I discuss how MRI introduced a "brain turn" in psychiatric practice, and I investigate MRI's new relation to notions of psychiatric illness. With the approach that new meanings are produced as scientific facts and medical scans travel from the laboratory to other social arenas I also analyze the production of meaning about HIV-related dementia through MRI between the settings of the psychiatric institution and the media.

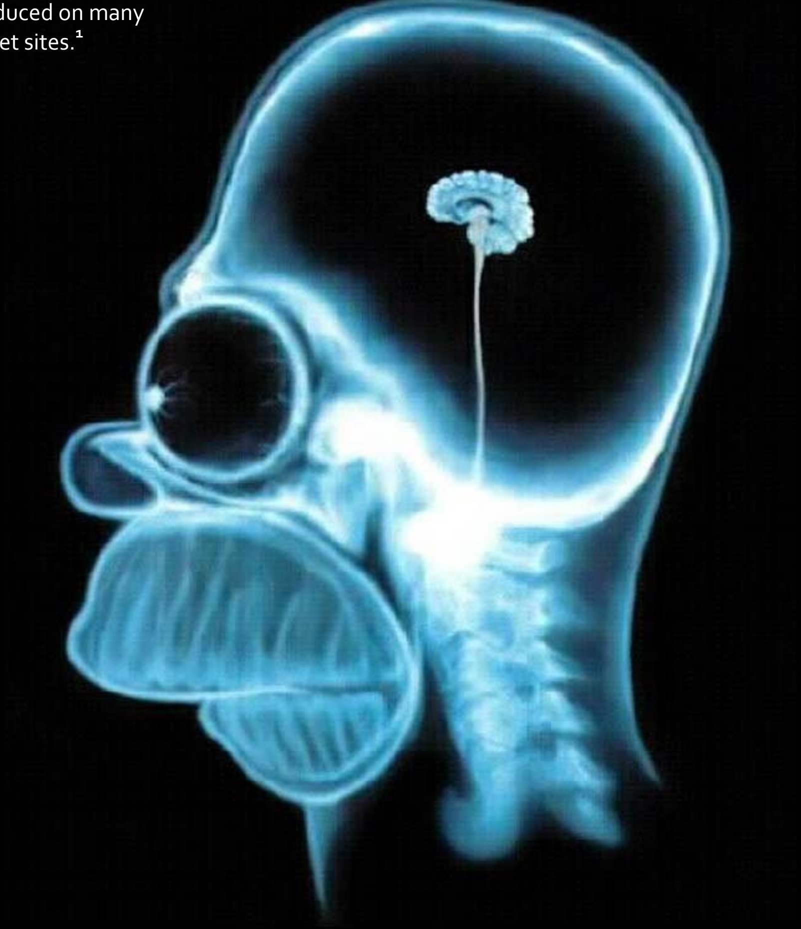
Chapter 5, "Quantifying normal anatomy", deals with another dimension of the MRI work done at St. Göran's Hospital. Whereas Chapter 4 had focused on the clinical use of MRI, here I address the strategies deployed by the St. Göran's group in their brain research, i.e. their attempts to characterize the normal brain with MRI scans. The focus is, on the one hand, on the concrete tools developed to handle the visuality of MRI scans and the subjective judgments of the observers; and on the other hand, the researchers' efforts to "psychiatrize" brain anatomy as produced with MRI.

Chapter 6, "Cells, flows and relaxation times", takes us to physicists and pathologists' attempts to stabilize the MRI gaze within the framework of laboratory science. This chapter is organized thematically, following two main lines of research: First, I inquire about the ways in which pathologists and physicists at Lund University Hospital tried to make sense of quantitative NMR measurements of bodily tissues. I argue that in the course of their work, the Lund researchers made MRI the bearer of a laboratory gaze. Second, I follow physicists' development of flow visualization with MRI. There I emphasize the messiness of the phenomena researchers attempted to grasp with MRI, and the use of models, phantoms and representation strategies to "capture" bodily flows in the MRI apparatus.

In a final discussion, Chapter 7, I return to my initial questions. I discuss the introduction of MRI in the light of the specific histories of MRI studied in the previous chapters and refer this back to the relations between specializations, gazes and mediation technologies. I then draw conclusions about the novelty of MRI and its place in the fragmented world of medicine.

Shorter texts called "Interludes" are placed between the main chapters. These interludes are meant as breaks for reflection on the cultural embeddedness of the MRI gaze. There I investigate a few ways by which MRI partakes in contemporary culture, with a focus on the interaction of medicine, popular culture and individual participation in shaping the meanings of the MRI gaze and MRI-mediated bodies.

Figure 3. Homer Simpson's brain seen with MRI/X ray. Image reproduced on many Internet sites.[1]



interlude

MRI:zing homer simpson

X-ray images functioned, and continue to function, as icons, fetishes, and artifacts of health, life, sexuality, and, most significantly, death. [...] I consider X-ray technology as a pervasive and perverse cultural apparatus—one that confounds the distinctions between the public and the private; specialized knowledge and popular fantasy; and scientific discourse, high art and popular culture.[2]

Lisa Cartwright, *Screening the Body* (1995)

The reasons why we want to see inside the body using MRI and other medical technologies are not limited to improving diagnosis or curing diseases better. MRI's place in the world lies in part beyond the clinic and the laboratory. Radiological images are cultural objects in a dual sense: First, the visuality of medicine may be understood as the professional and technified product of a broader visual culture, and cultural understandings of radiology penetrate the expert world of MRI research.[3] Second, radiological images or "scans" circulate and interact with visual cultures outside the clinic or the radiologist's office, and become entangled with other cultural representations. Media scholar Lisa Cartwright, whose words I have quoted here by way of introduction, has contended more radically that radiological scans work as a cultural apparatus for the medical gaze and, at the same time, blur the boundaries between expert knowledge and popular visual culture.

As a background to Cartwright's words I have placed an image quite widely available on the Internet: Homer Simpson's brain scan. This one is downloaded from one of the many Simpson sites that provide numbers of Simpson artefacts but it may also be found, for instance, in a medical website's explanatory material about image taxonomy.[4] On this false brain scan (which I refer to as MRI scan although it draws on different kinds of medical images), Homer's distinctive anatomy—mouth and eyes—is easily recognized. The picture has a distinctly radiological look: the bluish color of tissues on a black (as if empty) space, the high contrast and semi-transparency of tissues, and the outline of the skin over the skull are reminiscent of radiological features. Whereas the brain reminds of MRI images, the shadowy appearance of the neck bones brings to mind radiology's most familiar X ray scans.

Why do we (or why are we supposed to) laugh at Homer Simpson's MRI brain? First, radiological pictures usually have an anonymizing power, as it is difficult to recognize a person (socially identified with his/her external bodily appearance markers and interpreted through these) from the inner body only: as Lisa Cartwright writes, the body as seen on an X ray scan is "stripped of its overinscribed gender- and race-encoded epidermis and organs".[5] But Homer's physiology is defined as so deviant that he is made recognizable even through MRI; the surprise of identifying his fictional features on an MRI scan is the picture's first twist.

Second, the picture plays on the contrast between the realism of the modes of representation (we recognize the image as radiological, a brain scan, and we assume that a scan of Homer could actually look like this) and the main object of the brain scan—Homer's minuscule brain in a large, dark void, echoing to his apathetic eyes. In our modern culture of the "cerebral body", the brain is the repository of the human mind, personality, feelings, cognition and intelligence—Homer's walnut-like brain stands for an intelligence as developed as a bird's.[6] Homer's specific form of stupidity in the Simpson series provides the frame through which the fake MRI scan makes sense. Homer's brain MRI presupposes sophisticated skills in its viewers: the decoding of a popular culture icon as well as that of high-tech medical imaging. The picture's second twist is thus to be found between the brain "itself" perceived through our popular understandings of it, and the fictionesque use of MRI's modes of representation.

Homer Simpson's brain picture demonstrates the pervasive influence of cultural understandings of visuality on those of radiology, and reciprocally, MRI's iconic power in contemporary culture.[7]

[2] under the control of the authorities?

hierarchizing visions of MRI through clinical evaluation

In Chapter 1 I have summarized the early development of MRI (then called NMR imaging) in the UK and the USA in the 1970s. Here I reconstruct and discuss selected aspects of the early Swedish history of MRI before the installation of a first MRI scanner in 1984: How did Swedish researchers' interest in NMR imaging arise? Which understandings of MRI gained legitimacy in Sweden and how? I then follow up the first years of the first period of MRI in Sweden with an outline of the diffusion of MRI in the second half of the 1980s.

The first section of this chapter introduces the early trajectories of three Swedish actors who came to play major parts in Swedish MRI history:

radiation physicist Bertil Persson (Lund); psychiatrist Lennart Wetterberg (St. Göran's Hospital, Stockholm); and radiologist Anders Hemmingsson (Uppsala). In a second section, I focus on the shaping of definitions of MRI that led the Swedish Medical Research Council (*Medicinska Forskningsrådet*, MFR) to fund Hemmingsson's purchase and the evaluation of an MRI scanner at Uppsala University Hospital (*Uppsala Akademiska Sjukhus*, UAS) in 1984. In a third section, I analyze how MFR's decisions and the organization of Hemmingsson's NMR group were entangled with a categorization process that sorted MRI visions along two lines: clinical-radiological and experimental-physical. In a fourth section I summarize the main lines of the diffusion of MRI outside the control of the authorities.

Whereas the first section is to a large extent based on the actors' narratives as related in my interviews with them, the second and third sections build primarily on archival sources. The fourth section is mostly based on publications in the Swedish medical journal *Läkartidningen*.

FROM ANGLO-SAXON PROTONS TO SWEDISH INTEREST IN MRI

lund—aberdeen

At the medical University of Lund, the radiation physicist Bertil Persson had been working on the impact of radiation on bodily molecular processes since the 1960s. When I met Persson in Lund in 2003, he traced his interest in NMR imaging back to March 1981, and a conference in München on X ray hazards and safety, where he met a group of researchers from different UK universities.[1] Persson recalled in our interview that when the conference participants were out drinking beer one evening, he overheard in the buzz of the pub conversations recurring words about research and secret testing of a new technology. Persson made contact with those researchers, and in this informal context alongside the formal conference, he got to know how physicists, chemists and doctors were building NMR-imaging devices in the cellars of their respective universities.[2]

Back in Lund, Persson decided to learn more about his newly awakened interest. A few months later, he packed his luggage again and traveled to the UK "for bed-and-breakfast holidays with his family" during summer. He visited several universities and got to see the device John Mallard was working on in Aberdeen (on Mallard, see Chapter 1). Persson then made up his mind:

> *In Aberdeen, Prof. Mallard showed me the most secret device, that they were hiding in a closet... That was their first MR device, that was principally two large coils with a few small coils within, and everything was so primitively wrapped together with copper thread game and rubber. They showed me how it worked, how they could re-construct MR images... Then I could see it before my eyes: "This is so easy, we should be able to do that in Lund".*[3]

In Lund again, Persson started working on NMR. He kept cooperating with Mallard—in his own words: "Visited Aberdeen again in December 15, 1981 and imaged my heart".[4]

Persson also begun to attend international workshops on MRI, notably a key symposium held in Winston-Salem in October 1981, where leading MRI researchers presented their experience of research and clinical results, and their perspectives for the future. The different research lines and visions about NMR imaging that existed within the physics community were presented—and in part opposed: according to Persson, "the first bullets [were] shot". The symposium covered technological advances and orientation of measurement techniques, hardware and image reconstruction; which included fundamental issues about *what* MRI made it possible to image through the content of NMR signals. Available clinical results were presented and applications of NMR imaging for characterization of bodily tissues and tumor identification were emphasized; how NMR images compared to existing radiological technologies was also addressed.[5]

Some of the perspectives exposed at the symposium seem to have inspired Persson and contributed to his own positioning in terms of visions about MRI. Persson got in touch with Damadian at the Winston-Salem symposium and felt that they had similar conceptions of NMR technology.[6] One can find for instance a few words by Damadian that Persson wrote down amongst his symposium notes: "NMR penetrate the barrier to make medicine a quantitative science". These words sound like a motto that underlines the way Persson structures his autobiographical NMR/MRI history in our interview. In his historical narrative, Persson insists that what he wanted from MRI, and the technological developments he strove for, was never primarily to produce pictures, but to provide information about the molecular and cellular structure of bodily matter.[7] Persson's further notes—"Never mind Radiation // Nicht mit Röntgen // Non mes Rayon"—also tend to show his and the physicists' tendency to distance themselves from radiology, which already stood for crisp anatomical images.[8]

stockholm — L.A.

Psychiatry professor Lennart Wetterberg was one of the first Swedish doctors to explore MRI's powers of vision. Wetterberg, who had been appointed professor and chief psychiatrist at St. Göran's psychiatric clinic in 1974, recalls during our interview how frustrating the absence of imaging technologies for psychiatric patients was in the 1970s:

> *I especially remember two patients who had undiagnosed brain tumors and who had been in family therapy, among others. At the same time, these tumors were growing, and we had no possibility of examining the state of the brains in our patients. It was more or less the same situation as for lung doctors who treated tuberculosis before X rays came—they could only listen to the lungs, but not take pictures. The problem for us was that […] there was admittedly computed tomography in Stockholm, but the mentally ill had to wait at the back of the queue. When I referred the patients to Karolinska Hospital's radiology department, the referrals had to be processed by neurologists, and because of the limited resources the psychiatric patients were seldom given priority [and consequently, seldom examined].*[9]

It was in the USA that Wetterberg first heard about MRI. In the fall of 1978, Wetterberg had organized an educational stay at UCLA (University of California, Los Angeles) for a group of twenty Swedish medical students, as part of their education in psychiatry. Between 18 September and 13 October 1978, the students attended colloquia, exercises, and customized seminars held by prestigious names in American neuropsychiatry and related disciplines, among them Milton Miller, Robert Stoller, and William Oldendorf.[10] Oldendorf was a prominent neuroscientist (psychiatrist and neurologist) and had been among the firsts to conceptualize and build a prototype of computed tomography scanner in the 1960s.[11] Wetterberg recalls:

> *Then a professor at UCLA, Bill Oldendorf gave a lecture about the imaging of the brain with magnetic resonance technology [i.e. NMR imaging]. He said that there were several American companies that were developing medical applications of this technology. He concluded his lecture by saying "NMR is here to stay". I understood then that MR technology would be developing more, and I decided that I would try and get such an NMR device in Sweden for psychiatric research.* [12]

Back in Sweden, Wetterberg contacted the Swedish *Council for Planning and Coordination of Research (Forskningsrådsnämnden,* FRN*)* in 1979 and requested their funding for an NMR scanner for use in psychiatry. In his own words, their reply was that MRI "was an interesting technology but it could not be implemented before the year 2000". Wetterberg's own interpretation of their attitude is that those who worked to develop NMR imaging in the UK and the USA kept their work relatively secret and that MRI was hardly known at all in Sweden before the 1980s.[13] Wetterberg's next move was to reach the Stockholm County Council (*Stockholms läns landsting*, SLL). The county councils were (and still are, so far) regional political bodies which funded and controlled health care for their region, deciding among others which kind of care or patient groups should be prioritized, and which specialized care should be actively developed on a regional basis.[14] The County Council's reply in October 1982 to Wetterberg's demand for funding the acquisition of a NMR scanner formally acknowledged that "it would be extremely valuable to improve the diagnostic possibilities within the psychiatric field," but referred to "the difficult economic situation" to argue that "the acquisition of the magnet camera may not be realized within a foreseeable future". [15]

FRN and SLL were the usual key actors in the financing of health care technology (FRN for research equipment and SLL for clinical use). In parallel with his approaches to the County Council, Wetterberg defined another solution, through other actors than public decision-makers. He created a fund for private donations in November 1981, the "St. Göran's fund", for the purpose of funding several projects in psychiatric research. As Chapter 4 will show, Wetterberg would later redefine it as a fund for the purchase of an NMR scanner.[16]

Wetterberg mediatized his quest for a brain-imaging instrument. For instance, in March 1982, Birgit Rennerstedt, a journalist from the Swedish medical journal *Läkartidningen*, expressed her wish to "advertise a little for Karolinska Institute's fund for psychiatric research", which had by then collected about 20 000 SEK (the research at St. Göran's Hospital was part of the renowned Karolinska Institute).[17] Interviewed by Rennerstedt, Wetterberg described what he expected of MRI, which he had renamed "magnet camera": "It gives a quick answer where we today have to guess"—and "[w]e need it in order to be able to quickly give a proper diagnosis to patients with brain damage."[18] Wetterberg's arguments were not so much technical as *moral*, as he was quoted as saying:

> The new technical examination methods, both existing and upcoming, imply a breakthrough for psychiatry. It would be indefensible to halt in that situation. [19]

Wetterberg wanted to provide psychiatric patients with a visual window on their brains. When foregrounding psychiatric research and practice to attract public attention to his project, Wetterberg also seeded the growing mediatic light upon MRI with notions of a morally grounded imaging imperative.

uppsala

Radiologist Anders Hemmingsson was working at the department of diagnostic radiology of Uppsala University Hospital (UAS) in the late 1970s. Hemmingsson recalled in our interview in 2003 that he first became interested in NMR imaging after a discussion with his colleague Ulf Lindsjö, an orthopedist at UAS. Abroad Lindsjö had heard about a new imaging technology in development which had already shown exciting results: NMR imaging. Hemmingsson and Lindsjö decided to invite Raymond Damadian from the USA, who they knew had patented a first design for an NMR-imaging device. Damadian came to Uppsala in 1978. It then took about a year for Hemmingsson to begin to explore the possibility of getting funds for an MRI device for Uppsala.[20]

Hemmingsson kept in touch with Damadian. In October 1980 the first commercial whole-body NMR scanner, Fonar QED 80, was placed in Cleveland, actually a prototype to be evaluated.[21] In *Läkartidningen*, the NMR scanner was implicitly presented as a highly exclusive and expensive device.[22] The journal's sparse coverage of the early introduction of NMR imaging abroad raised the question of Sweden's position in what was presented as a race to be the first European country to get MRI:

> Sweden to get the first European scanner?
>
> [...] Sweden is well placed to get the first device in Europe. The radiology department of University Hospital in Uppsala has such a good reputation that Damadian would like a device to be placed there. They have had been working together for two years.[23]

In December 1980, Hemmingsson and physicist Bo Jung from Uppsala University's radiation physics department traveled to see MRI devices under development. In 1980 and 1981, Hemmingsson visited Fonar, Siemens and Philips. He also invited the companies to present what they could offer in 1981 and viewed Philips, Technicare and Siemens as first choices.[24]

Choosing a provider among the competing manufacturers was difficult, especially since not all of them had developed commercially available NMR-imaging equipment yet; many of them proposed research cooperations. Hemmingsson and Jung had been involved in earlier research cooperation between the diagnostic radiology department and Siemens on computed tomography (CT), which gave Siemens a credibility as potential partners in MRI. Among all these contacts, that with Fonar was intensive; according to Hemmingsson, Damadian offered him the post of director of the European division of his company—which he says he turned down, in his own words too bound to his academic work. [25]

In 1981 an MRI-project group was formed—then called "NMR group". A core group included Herman Lodin (chief radiologist at the diagnostic radiology department), Uno Erikson and Anders Hemmingsson from the diagnostic radiology department, Bo Jung and Christer Ytterbergh from the radiation physics departments, and members of the hospital direction. An extended group also gathered "representatives for the bigger existing clinics". The plan was also that Jung ought to contact the "NMR people" at UAS, to elaborate a "state-of-the-art" of NMR in clinical examinations.[26] The NMR group also worked to gain medical legitimacy and made contact with representatives from different medical clinics at UAS; they seem to have had the hospital's direction on their side in 1981.[27]

Hemmingsson told me that he also built up contact with political actors at the regional level (county council).[28] Hemmingsson's contact work at a local level may have had at least two purposes: firstly, it may have been part of creating local political support (asserting the county's interest and support for the project) for later funding applications; and secondly, it might be understood as a consolidation of the position of the project within UAS and the county, since the hospital would be owned and funded by the county from the turn of 1982/1983.[29] These efforts to gain support from local politicians made use of, and reinforced, the definition of MRI as a *clinical tool*. The part of the radiology department's activity financed by the county was *clinical practice* and to some extent *clinical research*—whereas other research depended on the university, i.e. government funds or external funds. In other words, the distribution of actors that Hemmingsson's group established contact with reflects the UAS NMR group's intention to establish themselves as clinical experts.

The above shows that Hemmingsson worked to establish and legitimate his clinical grounds for MRI, mostly in contact with authorities and other clinics at UAS. However, this line of action was paralleled with initiatives from the local authorities to explore the possibility of establishing an industrial cooperation on the development of MRI. The Uppsala County Council began to discuss with an Uppsala-based firm, Scanditronix (Instrument AB Scanditronix), the possibility of cooperation with UAS on developing their own NMR-imaging technology. Hemmingsson's understanding is that the County Council acted with a local political perspective aimed at supporting local industrial dynamics and cooperations between private companies and university; but he gave that possibility of cooperation a low priority because Scanditronix had no readily available technology.[30] What the hospital's attitude was to this plan is unclear; at the end of 1981, they were still in touch with Scanditronix.[31] About then, Hemmingsson and his colleagues invited SPRI (the Swedish Planning and Rationalization Institute of the Health and Social Services, an authority concerned with the efficacy of clinical practice), together with people from Uppsala's departments of diagnostic radiology, orthopedic surgery, and radiation physics, for a "discussion about NMR and, among others, what possibilities exist *of realizing a development project* with the new technology at the [Uppsala] hospital".[32]

A core group was thus emerging at UAS around Hemmingsson, which mobilized people from different disciplines and decision-making positions in order to create consensus around the project they aimed to realize: getting NMR imaging to Uppsala. Hemmingsson was working towards a joint application to the Swedish Medical Research Council (*Medicinska forskningsrådet*, MFR), the Cancer Research Foundation (*Riksföreningen mot cancer*, RmC), both of which funded medical research projects every year: the former with government funds, and the latter with private donations. The application to MFR would have to be forwarded to the National Council for Planning and Coordination of Research (*Forskningsrådsnämnden*, FRN) who funded costly research equipment for the different disciplines covered by the several research councils (natural sciences, medicine, technical research etc.). The application was to be sent in January 1982, and the project was entitled "Nuclear magnetic resonance (NMR) for whole-body examinations in vivo". Hemmingsson described the project's purpose as to "evaluate and develop NMR imaging for clinical diagnosis".[33] Hemmingsson had thus placed his project in an open—and ambiguous—position: would his NMR group act as developers or clinical evaluators?

Swedish interest in NMR imaging was thus awakened in contact with US and British researchers around 1980. The Swedish researchers whose early MRI histories have been presented above went into the MRI race with different purposes with regard to the technology: where radiation physicist Persson was motivated by the quantitative science of bodily molecular interactions that NMR promised, psychiatrist Wetterberg saw a chance to give his discipline and patients access to brain imaging, and radiologist Hemmingsson and physicist Bo Jung seemed to want to extend radiology's apparatus with NMR's new physical means. Similar divergences in what MRI was to be used for to that presented by Stuart Blume—cancer detection or imaging as such—thus appear to have been present in the early Swedish history of MRI.[34] At the same time, other researchers such as radiation physicist Rune Walstam in Stockholm and surgeon Tore Scherstén in Gothenburg also came to hear about NMR imaging; as certainly did many more. A striking feature of this early period is that Swedish actors began to shape their own plans about MRI parallel with each other and often in contact with scientific communities abroad; it is probable that most of them had not heard about other early Swedish MRI visions.

TOWARDS CLINICAL EVALUATION

In their announcement of MRI's national evaluation in 1982, the Swedish Medical Research Council MFR presented themselves as the initiators of MRI's introduction in Sweden. A few months later, Hemmingsson's group in Uppsala was officially chosen as the site where the concomitant two-year evaluation of MRI was to be conducted. Not only would MFR fund the clinical assessment of MRI together with RmC; it recommended at the same time that no other MRI scanner be purchased until the clinical value of MRI against existing technologies had been established.[35]

That MFR asserted their influence regarding MRI may not be so surprising, given that they were a major financier of medical research and that the costs of an MRI scanner were extremely high for hospitals and research groups. What is more interesting—and it is the purpose of this section—is to explain how MFR's own purposes in evaluating MRI were shaped, and how their ways of momentarily gaining control of MRI created hierarchies between different visions of MRI.

enter the medical research council (MFR)

MFR's interest in NMR probably originated in Tore Scherstén's work in the late 1970s. In our interview, Scherstén explains that he was a surgeon at the Sahlgrenska Hospital in Gothenburg, involved in medical research and mostly active within chemistry (quite an unusual combination, as he points out). In these settings, he worked to introduce chemical NMR spectroscopy in clinical practice. Scherstén contacted Raymond Damadian from the USA and invited him to Gothenburg to talk about NMR spectroscopy, but Damadian also presented his then newly developed NMR-imaging scanner. According to Scherstén's own narrative, this was where his interest in MRI was born.[36]

Scherstén was also the chairman of MFR's "priority committee" for surgery which also dealt with radiology. That made him one of the most influential people at MFR, together with Henry Danielsson, MFR's secretary, and Håkan Eriksson, vice-secretary since 1978. MFR was made up of researchers elected by the medical research community. Its role was to distribute government funds to medical research projects every year; which projects would be funded was studied in twelve to fourteen priority committees which each covered one specific domain such as surgery or psychiatry. In addition to the priority committees, temporary "initiative groups" could be created to handle more specific questions and define specific initiatives to be undertaken by MFR.[37]

Before 1982, MFR had been involved in broader issues concerning the scientific rationalization of health care.[38] In the seventies, the rising costs of health care in general, and more specifically the uncontrolled diffusion of the costly diagnostic imaging technology CT (computed tomography, earlier called computer-assisted tomography or CAT), alarmed the American government and authorities, soon followed by other Western countries. Efforts were made to contain the rising costs of health care technology: its purchase and its use. In the late seventies, MFR created committees for health care research and began to think of such actions as organizing "consensus conferences" on an American model, aiming to actively involve researchers and clinicians in defining guidelines for practice including notions of economic efficiency of care.[39] MFR created their own section for health care research in 1977, took part in the creation of a Scandinavian cooperation on health services research, and created in the fall of 1980 a special initiative group for research within "method development and method control" (later called "evaluation of medical technology"), whose chair was Tore Scherstén, and the purpose of which was to study methods and technologies "in need of evaluation and analysis". MFR also participated in an international symposium on technology assessment in 1981.[40]

The task of MFR's initiative group for the evaluation of medical technology was soon defined as "to identify the technologies with highest need for evaluation" and "to propose research projects" during the years 1981/1982 "that may render such evaluation easier". In their official documents, MFR described the work of this initiative group as method development.[41] The absence of visible evaluation projects from MFR's archive suggests that the assessment of NMR was MFR's first concrete investment in the evaluation of medical technologies.

The idea that the rationalization of health care and of technology diffusion ought to be scientifically orchestrated was one of the reasons why MFR considered that they had a part to play in the introduction of MRI in Sweden.[42] MFR's explicit ambition was thus not to take a "political" role of coordination of health care resources, but to promote the birth/growth of scientific fields such as health care research and assessment of medical technology and practice. The boundary between political and scientific rationalizing of health care was seemingly rather fine.

a contested chronology of origins

MFR's goals in funding the purchase and evaluation of an MRI scanner are not controversial. What is more contested is the evaluation's chronology of origins: Whose initiative was it? Both MFR and Uppsala deliver(ed) narratives of "being the first". This subsection explores briefly the two versions of the history of the MRI initiative of the spring of 1982 and focuses on MFR's reception of MRI-related applications in 1982.

On the one hand, Scherstén describes the process from his and MFR's interest in NMR imaging to Sweden's first MRI scanner as rather straightforward in our interview: He brought up the question of introducing MRI for scientific evaluation to the surgery/radiology priority committee, with the argument that MRI would inevitably spread in Sweden, but that it would be better if it happened in a scientifically controlled way, "so that we know what we're doing, what we invest in, and what advantages it offers—both clinically and scientifically." According to Scherstén, the priority committee then recommended the council committee to take a specific initiative on NMR, which did not meet any resistance.[43] The intended technologies were both MRI and NMR spectroscopy for studies of metabolism. When the initiative was accepted, MFR took informal contact with hospital actors to assess the interest in starting MRI research. Two potential centers were identified: Uppsala University Hospital for their radiological competence, especially shown in their experience of CT, and Lund University Hospital for their recognized competence within NMR studies of metabolism. At UAS, Scherstén was in contact with Hemmingsson. Soon, MFR decided that UAS was the best alternative for an evaluation of the clinical value of NMR imaging. MFR's original intention was also to recommend a moratorium on further purchase of MRI after funding the purchase and assessment of one device—to be placed in Uppsala. In an interview conducted in 2004, Håkan Eriksson, who was MFR's vice-secretary in the early 1980s, insists that MFR's initiative on NMR was decided before project applications were turned in, and that Uppsala soon emerged as the most adequate candidate.[44]

On the other hand, there is no archival evidence of MFR's interest in NMR previous to the reception of the applications in 1982.[45] The documents that can be found rather show that MFR's joint initiative for the evaluation of NMR "as a medical diagnostic method" was formulated and formally adopted in the spring of 1982. In January 1982, MFR and the Council for Planning and Coordination of Research (*Forskningsrådsnämnden*, FRN) received applications from three different research groups to purchase NMR equipment, and formulated their commitment to introduce MRI to Sweden in their comments on one of the applications:

> The development of NMR technology for imaging purposes is of major interest and Sweden has to take part in this evolution. This year, three groups are applying for funding to participate in this development. [46]

The three applications came from different directions: one from radiation physicist Bertil Persson in Lund, one from radiologists Anders Hemmingsson and Herman Lodin at the Uppsala University Hospital's radiology department, and one from radiation physicist Rune Walstam at Karolinska Hospital in Stockholm.[47] Whereas both Walstam's and Hemmingsson/Lodin's applications envisaged an evaluation of NMR imaging for medical diagnosis, Persson's concerned method development for studies of bodily flow (such as blood flow), which included NMR. Persson had also sent an application to FRN concerning equipment to build a whole-body NMR scanner.[48]

The three NMR applications were assessed and ranked—as all others were—by MFR's priority committees. There, they were sorted into two categories: On the one hand, Persson's project was to be considered by FRN's committee for funding of costly research equipment (FINDU), and on the other hand, Hemmingsson/Lodin's and Walstam's applications were to be specifically discussed and weighed against each other. The way joint decisions were made in practice is that MFR made their own ranking and sent this as a recommendation to FRN and FINDU. FINDU then considered the recommendations from each research council (MFR and respective research councils for other scientific disciplines) and made a final proposal to FRN, who took the formal decision about attribution of funds for costly research equipment.[49] Concretely, it was thus MFR who made the first decisive rankings in issues of funding costly technology and therefore had the strongest influence (as compared to FINDU and FRN) in deciding which costly medical research equipments should be funded.

How did MFR value the three applications received? Persson's application for development work and experimental exploration of NMR technology was considered by MFR as a necessary investment in developing technological competence in Sweden, as the following comment on his application suggests:

> Diagnostic imaging, dynamic studies of the flow-measurement type, as well as metabolic studies using phosphorus NMR. Development in this field is currently very rapid. For us in Sweden to be able to keep up with this development and benefit from the gains that this technology potentially offers we need investment that also provides for development work and research.[50]

Persson's experimental work on flow measurement and imaging with NMR was assessed in very positive terms which stressed the importance of Sweden's developing a scientific competence in NMR-imaging technology. However, Persson's project was not considered as clinical. MFR decided that the clinical side of MRI was to be addressed with a much larger project including the purchase of a commercial MRI scanner for about five million SEK for an evaluation of NMR's clinical value. In February 1982, MFR brought up with SPRI the question of assessing MRI and agreed on an evaluation conducted at one sole place in Sweden.[51] Only *one* device was to be funded and evaluated, in *one* location and under the responsibility of *one* group. MFR's motive was to warrant the *economic efficiency* of MRI as part of the health care system, as their comments to Lodin/ Hemmingsson's project suggested: "[...] discussions have led to an international assessment of the different projects to get clarity as to where the funds shall be invested. *Sweden could hardly afford parallel progress of the same sort in two different places.*"[52]

MFR therefore postponed the decision about where to place the evaluation (Uppsala or Stockholm, or elsewhere). MFR and the Uppsala group had contacts during the spring of 1982, mutually informing each other about their perspectives on the MRI-assessment project, and seemingly leading to a tuning of their visions of what would be done with MRI—how, is the object of next subsection.

UAS & MFR: coalescing into clinical evaluation

UAS' line was double: Hemmingsson's group positioned themselves explicitly as *both developers* of the technology and *clinical specialists* towards national authorities and the medical actors at UAS. Which kind of contact did MFR and UAS have during the spring of 1982, following the application, and with which consequences for UAS' formulation of the project?

In March 1982, Henry Danielsson, MFR's secretary, presented MFR's intentions in a meeting with UAS' NMR group. He revealed, or probably confirmed, that Uppsala's and Karolinska's respective applications were in competition for MFR's MRI funds, and announced that MFR would need time to make the final decision, with the help of foreign consultants. This was a way to present MFR's unappealable decision made in February to invest in one single place—and one device. Danielsson justified this premise not only as a consequence of MFR's difficult financial situation, but most of all, as a result of the experience drawn from the costly diffusion of computer tomography in Sweden. He said:

> No hesitation about coming into NMR, but as an isolated investment. We will not repeat the mistake [that was made] with CT.[53]

"The mistake with CT" referred to radiologists' and hospitals' enthusiastic acquisitions and costly use of CT scanners from public funds in the 1970s, resulting in authorities' anxiety in the early 1980s in the USA and to some extent, in Sweden.[54] CT had been an imaging technology for radiologists in Sweden; to position NMR imaging in the continuity of CT meant implicitly defining NMR primarily as a tool for clinical use and clinical research, in the hands of radiologists.[55]

During that meeting, Danielsson outlined the two possible scenarios for establishing MRI in Uppsala: either buy a commercially available device, or enter into development cooperation with Scanditronix. But Danielsson made it clear that MFR's priority was for the assessment to begin as soon as possible, excluding any other alternative than purchasing a commercial NMR device, and Hemmingsson made it clear that he supported Danielsson's position.[56] In other words, developing and building their own MRI technology did not come into question in the evaluation project; what MFR was interested in was clinical applications and promoting scientifically controlled diffusion of medical technology.

Although Hemmingsson soon positioned his group along MFR's line of purchasing a commercially available MRI scanner, he did not sacrifice the vision of developing MRI in Uppsala. This is rather clear in a draft, written a couple of weeks later, intended to be a letter to the chairman of FINDU, Arne Gadd (to my knowledge, this version of the letter was not sent):[57]

> [In our view] the purchase of a commercial, well-functioning device is therefore essential, so as to be able to conduct an adequate assessment and further development of the technology as soon as possible. The knowledge that is received hereby may possibly in a second phase lead to developing our own apparatus in the country.

The formulation above realized the paradoxical turn of rendering the goal of in the long term developing Swedish NMR technology not only compatible with, but mostly dependent on MFR's preferred alternative which was to purchase ready-made technology.[58]

Without losing the perspective of developing MRI further, Hemmingsson's group had thus re-positioned themselves as what the clinical frame of MFR's project demanded: *users* of technology led by a radiologist.[59]

CLINICAL RADIOLOGY VS. EXPERIMENTAL SCIENCE

MFR's decisions and boundary-work

MFR's MRI decisions were of two kinds: First, the formation of their own "initiative" on NMR, and second, their decisions about the funding of the three MRI-related project applications. Their formulations and decisions can be understood as "boundary-work", to use a concept that sociologist Thomas Gieryn introduced in 1983. Gieryn defined boundary-work as the "attribution of selected characteristics to [an institution] (i.e. to its practitioners, methods, stock of knowledge, values and work organization) for purposes of constructing a social boundary that distinguishes some intellectual activities as [outside of that institution]."[60] Similarly, MFR's decisions and public judgments of MRI applications defined whether visions of MRI should be understood as medical, and which should be ranked as more important. In this subsection I analyze how MFR's decisions operated as boundary-work, and with which immediate consequences for the divergent views on MRI in 1982.

In April 1982, as discussions about the evaluation project went on within MFR and, at a higher level, within the "joint committee" (*samarbetsnämnden*) for the different national research councils, MFR made public their "joint initiative of MFR and RmC for the assessment of nuclear magnetic resonance (NMR) as medical diagnostic method". The document formulating MFR and RmC's initative reads as follows:

> The joint committee has decided to propose that MFR and RmC jointly initiate a scientific evaluation of the [NMR] method from an efficiency and safety perspective. The intention is that the method shall be compared with presently available methods [...]. The joint committee considers that such an initiative from MFR's and RmC's side is of very high importance for the health care decision-makers' planning for purchase of advanced diagnostic equipment.[61]

As described in that initiative document, MFR and RmC's project formulation insisted that the evaluation was to focus on efficiency and safety. In contrast with Hemmingsson's MRI application's original aims which were "evaluation and development", MFR had formulated the project they would fund as "use and assessment of [NMR] in clinical diagnosis".[62]

RmC announced the initiative in *Läkartidningen* as of even more clearly clinical, radiological character, as their notice shows:

> Another grant is dedicated to the evaluation of a new method, whose uses include the diagnosis of tumors. The method is called NMR (nuclear magnetic resonance) and resembles computed tomography with the difference that it uses non-hazardous radio waves instead of X rays. Together with the Medical Research Council, RmC has allocated 2 million SEK for an evaluation of this method.[63]

A new method for the diagnosis of tumors, "resembl[ing] computed tomography": RmC and MFR categorized MRI as a step further on in a clinical-radiological continuity.

In May 1982, MFR made the formal decision to fund Persson's application for an experimental exploration of NMR technology (the funds amounted to 150 000 SEK the first year; Persson had applied for a total of 500 000 SEK). MFR also designated Henry Danielsson and Tore Scherstén as MFR's representatives in the further study of where MFR's MRI device should be placed for evaluation. The choice between Hemmingsson's and Walstam's applications was postponed.[64] In this phase of MFR's decision-making process, the application from Walstam's group was in a seemingly weaker position. However, it is impossible to know on which grounds Walstam's application was struck off the lists and the comment "rejected" (*avslag*) added, and unfortunately, MFR's different lists are undated. What can be known is that the Uppsala group was formally chosen for the MRI evaluation by the "working group" in charge (Danielsson, Scherstén and two representatives of RmC) in June 1982, and that the reasons for that choice are not documented in MFR's archives.[65]

In July 1982, Danielsson made a telephone call to Hemmingsson to announce, informally, that UAS' department of diagnostic radiology had been chosen for the assessment of MRI and would get funds to conduct it.[66] An official notice in *Läkartidningen* entitled "First NMR equipment to [Uppsala] University Hospital" formulated the event as Uppsala's victory in a competition set by MFR and RmC:

> [Uppsala] University Hospital won the competition for the first NMR equipment in Sweden. The Swedish Cancer Foundation [RmC], the Swedish Medical Research Council [MFR] and the Council for Planning and Coordination of Research [FRN] invest a total of 7 million SEK in the purchase and evaluation of the NMR device.[67]

Through their decisions and public formulations, MFR thus asserted that the project of getting MRI to Sweden was their own initiative, and displaced researchers' formulated visions so as to align MRI with their own concerns: to establish scientifically controlled diffusion of medical technology through assessment of new technology. What their decision sealed was that MRI was to be Sweden's first example of official assessment of medical technologies.[68]

MFR also asserted their decision to fund UAS' device with a recommendation to the Federation of County Councils (*Landstingsförbundet*, LF) that the county councils—and therefore, public hospitals—should not invest in MRI until its evaluation had been concluded. MFR officially informed LF that "[b]efore the method [MRI] begins to be used in Swedish health care, it is fundamental according to MFR and RmC that its diagnostic value be compared with computed tomography, emission tomography, and ultrasound imaging".[69] This resulted in October 1982 in LF's directive to the county councils and municipalities not to purchase MRI devices; symptomatically, LF added a recommendation to be cautious also as regards investments in CT.[70]

In one single year—1982—MFR thus managed to implement their vision of what MRI should be considered as, at least temporarily: a clinical, radiological technology to be further introduced and used in the future on the basis of scientific evaluation results.

In contrast to the Uppsala evaluation's seven million SEK, Persson's experimental project was also to be funded with half a million SEK.[71] Although MFR judged Persson's proposal in very positive terms (see subsection *A contested chronology of origins*), they established a boundary between the two projects which were then treated as of different kinds. This boundary and categorization imprinted a hierarchy between two definitions of MRI: MRI as a research object and a technological complexity to master through experimental physical-chemical technical work was recognized as valuable, but held apart from the main arena which was that of clinical, radiological imaging technologies.

uppsala's internal demarcation lines

With MFR's decision as a starting point, UAS' shaping of the project accelerated from the summer of 1982. Material questions became central to the project: identifying and choosing a provider including nature of research cooperation, planning the installation of the MRI scanner, securing funding of the installation and use of the device. Here I outline the organization and focus of Hemmingsson's group and discuss them against the background of the categorizing and separation of MRI work into clinical-radiological and experimental research.

An important change in focus within UAS' MRI project was the growing importance of the technical and financial questions about the installation of the future device.[72] Hemmingsson's group soon integrated representatives of UAS' department of medical technology; installation became one of the originally four subgroups working on the project.[73] Problems concerned the choice of a site to house the MRI device, i.e. a site which would support its weight; the protection from electro-magnetic disturbances from and to surrounding activities; the installation of cooling devices with liquid helium if the device had a superconducting magnet; the impossibility of having certain kinds of metal in the vicinity of the device. Hemmingsson stressed the urgency of resisting local interests to make UAS' project into a local industrial cooperation with Scanditronix:

> Note that people at the county council are rumored to be interested in cooperation with Scanditronix within the NMR project. Here we must ensure, with the support of the responsible authorities, that equipment as nearly ready to use as possible can be purchased as quickly as possible.[74]

After visiting a few industrial producers of MRI scanners in 1982, Hemmingsson's group chose and purchased a superconducting MRI device from Siemens in 1983.[75] Among all possibilities, superconducting equipment had higher field strength and produced sharper images than devices with lower field strength. In a way, this choice set some premises for what MRI was intended to be. At that point, the planning of the installation had started, and it had been decided that the device would be installed outside the diagnostic radiology department, for logistic reasons.

Hemmingsson's group also worked at formulating their own role in the history of MRI, that of pioneers. They organized a "hearing" in September 1983, where they presented a brief chronology of how UAS' diagnostic radiology department came to be the first to get NMR in Sweden—building up a success story, that of the pioneers—and optimistic visions about the future. Following the clinical radiological line, Hemmingsson presented MRI as a tool for creating anatomical pictures of higher quality than available technologies.[76]

But Hemmingsson and Jung also mentioned another goal, that of accurate measurements "with different pulse sequences", which implied coming deep into the technology, into the way information was generated to produce pictures: Pulse sequences were the software part of MRI and commanded which magnetic stimulation was sent into the body and how the reception of body signals was done—thereby which kind of information was created in/collected from the examined tissue. In NMR imaging's early years—including the 1980s—many of these pulse sequences were designed by MRI researchers themselves. The scientific work was planned optimistically, and laid an emphasis on phantom studies and simulations, with a focus on examination tests and studies of the relevance of proton density and relaxation times, for pictures and measurement data.[77]

Hemmingsson and his closest collaborator, the physicist Bo Jung, thus kept and reinforced the duality they had outlined earlier in their application to MFR: they would conduct research into clinical radiological applications and their assessment, but would also conduct a scientific and experimental exploration of MRI.

This internal demarcation line within Hemmingsson's project group was also reflected by his new collaborators. In 1983, UAS' NMR group on the one hand established cooperation with medical researchers within Uppsala, and recruited Kjell Bergström, chief of the neuroradiology clinic. Bergström would formally work as a research assistant and would be responsible for the important neuroradiological part of the group's research, expected soon to be ready for clinical trial (Bergström had participated in earlier discussions about Uppsala's NMR project). On the other hand, Hemmingsson recruited other specialists such as Anders Ericsson, a physical chemist from Ehrenbergska Institute in Stockholm, and soon afterwards physiologist Göran Sperber who had competence in physical modelling and programming.[78]

In March 1984, Hemmingsson still described the aim of his MRI project as "to evaluate and further develop NMR imaging for clinical diagnosis", with the focus on the diagnosis of different tumours and follow-up of their treatments, and comparison with other imaging methods. His description was exclusively centered on the clinical use of MRI; yet he kept the dual formulation that would characterize his group's position in their first years of research.[79] Thus, by constructing a clear clinical/experimental boundary and organizing project work along the two sides of it, Hemmingsson could at the same time fulfill the (clinical) expectations of their financiers, MFR and RmC, and pursue his own scientific (experimental) goals.

The almost six-ton Oxford/Siemens MRI magnet, with a field strength of 0.35 tesla, was installed at UAS on August 28, 1984; the event was set in focus in the local press with optimistic front-page statements that announced MRI's arrival in clinical radiology's arsenal: "The plan is to use [the magnet] in routine care after the [three-year] trial period".[80]

TOWARDS UBIQUITOUS MRI?

Together with their decision in 1982 to fund the evaluation of MRI, MFR had recommended that no more investments in MRI should be conducted before the evaluation report which was originally expected for 1984. The Federation of the County Councils (LF) first reproduced this directive in 1982, and after the two-year delay in the evaluation start, modified their instructions to the county councils in 1984, recommending concentration of NMR on regional hospitals.[81]

Before the evaluation even started in Uppsala, several hospitals began to plan for the purchases of MRI devices; and while the evaluation was ongoing, hospitals and research groups negotiated with their respective county councils and implemented MRI without waiting for the conclusions of the evaluation—in which some of them also took part. The following chapters will present more thoroughly the early MRI work conducted by physicists and pathologists on a "home-made" scanner in Lund in the early 1980s and by psychiatrists at St. Göran's Hospital in Stockholm from 1984 onwards (see Chapters 4 through 6). Another example is that of Professor Erik Boijsen, chief radiologist at Lund Hospital's radiology department in the early 1980s, who said in an interview in 2003 that he made plans for the purchase of an MRI scanner as soon as it was known that Uppsala was to get a device for the national evaluation. Boijsen depicts the situation as a race in which his goals were twofold: get his department started with MRI before he retired; and make Lund's radiology department a counterforce to Uppsala's.[82] Karolinska Hospital in Stockholm also investigated the possibility of purchasing their own MRI device.[83] By the end of the evaluation in 1986, five hospitals had installed and were using MRI: St. Göran's, Lund, Uppsala, Karolinska University Hospital, and Umeå University. MRI scanners were installed in other hospitals at a sustained pace: Malmö and Örebrö in 1988, a private clinic in Växjö in 1989, Linköping, Falun, and Sahlgrenska Hospital in Gothenburg in 1990 (and an additional device in Lund in 1990).[84]

Swedish MRI researchers were early to appropriate the economic rhetoric of the evaluation to argue for a broader diffusion of MRI. For instance, Lennart Wetterberg's group demanded in 1984 that all university hospitals should have their own MRI scanner, with the aim "to give politicians and decision-makers factual information [on MRI] as a help for decisions", and Anders Hemmingsson proposed in 1986 that MRI "should be more broadly available, primarily by purchasing MRI devices for all regional hospitals". The argumentation of Wetterberg's group was even bolder and suggested that low-field MRI might become a routine instrument for health screenings.[85] Furthermore, they put forward the argument that MRI was an established method for certain diagnostic indications, and that the diffusion of MRI was inevitable in 1984: "The discussion in the USA is no longer about MR or not MR, but about which field strength should be chosen."[86] The argument that MRI was spreading rapidly abroad also appeared in documents and publications, stressing the urgency of addressing MRI's diffusion in Sweden.[87]

The MRI devices purchased by the Swedish hospitals in the 1980s differed in design and in the representations they could produce.[88] MRI researchers' arguments about the value and diffusion of MRI were framed by economic concerns, which provided a platform for researchers' negotiations about what the optimal MRI device was: low-field or high-field. "An intense debate has been taking place for several years", the SPRI evaluation report read in 1986, "concerning the optimal field strength for different purposes."[89] Where high-field MRIs stood for ever crisper anatomical images, low-field MRIs were argued to have a much worse resolution (roughly, worse level of detail and contrast on the images)—but they were far cheaper.[90] Some researchers like Bertil Persson also argued that the kind of information MRI could provide on living tissues was different in low and high fields, which for Persson was an argument for conducting research with low-field MRI.[91]

On economic and scientific grounds, Hemmingsson's group staged low-field and permanent/resistive devices as cheaper and less advanced than the more up-to-date and clinically higher-performing superconducting scanners: "The image quality is better at higher field strength, which is why superconducting devices are the most usually chosen today."[92] Thus, the basis on which low-field MRI was dismissed, he argued, was the images' pictorial quality. (Another main argument for high-field MRI was the envisaged possibility of conducting MR-spectroscopy in the future.[93])

To present superconducting devices as already a winner was also to suggest that they were the given future of MRI technology at large. In Hemmingsson's vision, MRI was a technology which should be used in larger regional or university hospitals; which fits well in the discourses of economic constraints and limitation or concentration of high-technological resources. But another side of his argument was that MRI should be used in specialists' close connection with research and advanced care, which justified costly investments in superconducting MRIs and made high-field MRIs an implicit norm. The fact that the national evaluation was conducted on a high-field superconducting scanner also helped to make high-field into a norm for MRI.

I bring up the issue of low-field and high-field MRIs because it illustrates well that continued "boundary work" took place in a dynamic of expansion of MRI into Swedish health care and its clinical radiology. Underlying the debates about low and high fields were tensions about the definition of who was a legitimate user as the user group of MRI expanded from one hospital/national evaluation to more and more hospitals and outside of research settings. Intertwined within this boundary work were tensions about the directions along which the MRI gaze should be used and further developed (cf. following chapters).

However, MRI's user domain had two dimensions: one of these was the hospitals themselves, and the other was the medical professions which were integrating MRI in their knowledge production. The increasing presence of MRI in Swedish university hospitals and the increasing production and circulation of MRI-research/practice results abroad were paralleled by (and certainly promoted) the growing interest of more and more medical specialties in the new technology in Sweden. This is reflected, for instance, by the increasing diversity of MRI publications in the Scandinavian radiology journal *Acta Radiologica*,[94] and in the program of the annual national medical congress, *Läkaresällskapets Riksstämma*, through the 1980s.[95] However, MRI was *clinically* used mostly within the range of radiology.[96] The picture that emerges from these sources is that, from being presented to the medical audience as a general technology with multiple possibilities, MRI was soon broken down into more specialized topics within a range of corresponding clinical professions under radiology's roof.

It seems that the national health care authorities could not greatly influence the deployment of MRI in the country. SPRI, and later, the new Swedish Council of Technology Assessment in Health Care (*Statens beredning för utvärdering av medicinsk metodik*, SBU) produced reports in which they followed the diffusion of MRI in Swedish health care and the diagnostic possibilities afforded by MRI. In these studies, the authorities kept reassessing how many MRI devices the country needed—hardly keeping pace with the apparently uncontrolled diffusion of MRI in Swedish medicine.[97]

I want to suggest that the scenarios of expansion of MRI reveal divergent utopias of the institutionalized transparent body: Wetterberg's scenario of "MRI for all" is one where the possibility to image everybody to identify potential somatic problems should be implemented; it is a logical expression of a technological imaging imperative acting on the premises that bodies are actually transparent if only we use available imaging means. In contrast, the vision of "MRI to the specialists" confers imaging-technology powers that need be domesticated and kept under control. Although it is based on the same fundamental idea that the technological gaze will spread its eye through ever more hospitals into ever more patients' bodies if not kept back, this vision that MRI should be confined to the hands of specialists argues that the possibility of the transparent body should be institutionalized and constrained, and its instrument—MRI's imaging powers—set in focus, scrutinized and tamed. With such an approach, the picture that emerges from the 1980s is that MRI's radiological vision escaped the authorities' ambitions of centralized scientific control.[98]

CONCLUSION

This chapter has shown that early parallel visions of MRI emerged in Sweden in the late 1970s and took concrete shape in the early 1980s. As MFR gained some control through funding, defining MRI's evaluation as theirs, and having LF adopting their containment recommendation, they grounded their vision of MRI as a clinical radiological tool. In contrast, the continued diffusion of MRI in the second half of the 1980s was, although undramatic in numbers, seemingly uncontrolled. The MRI researchers' arguments for an increased diffusion of MRI illustrate the discursive making of an imaging imperative. The attention devoted to MRI in medical contexts during that period *(Läkartidningen, Läkaresällskapets Riksstämma)* suggests that MRI was dominantly integrated as part of radiology and its subspecializations (for instance orthopedic radiology).

MFR's recommendation to LF in 1982 and LF's subsequent directive show that these two authorities actively contextualized MRI as part of the historical development and integration of tools in clinical radiology—as though MRI was an improved version of CT—and therefore categorized MRI as a clinical radiological device. As soon as it was authorized in the country, and in line with MFR's earlier warnings, MRI was made a political subject in the continuation of CT; MRI's gaze was also to be assessed on the basis of the performance of other radiological technologies.

The naturalization of that narrative makes visible the hierarchies of visions constructed during that early period, which officially established MRI as a clinical radiological tool and acknowledged but marginalized another vision, Persson's experimental MRI exploration of the body with a physical and cellular-molecular perspective. Hemmingsson's group could, in contrast, plan for experimental work as they had succeeded in situating themselves on the "right" (clinical) side of MFR's boundary between clinical and experimental research—which gave them access to an MRI device. Wetterberg's vision of MRI as psychiatry's new window on the brain was even further marginalized in history-writing, as the following excerpt from a newspaper article written in 1985 suggests—by then two MRI scanners were installed in Sweden, at UAS and St. Göran's Hospital:

> We were wrong in writing that the magnet camera in Uppsala was the only one of its kind in Sweden. This was because the article relied on information from SPRI [The Swedish Planning and Rationalization Institute of the Health and Social Services] [...] in which nothing was mentioned about the magnet camera at St. Göran's. "The official health care-Sweden doesn't really want to know that our camera exists, since it was not bought with public funds [...]," says Lennart Wetterberg.[99]

(The place of St. Göran's Hospital's psychiatric research in the history of MRI will be further addressed in Chapter 4.)

I have demonstrated in the introductory chapter that the primary user group for MRI was unclear in the technology's early years abroad. As I have also argued there, Stuart Blume's reflections on the earlier history of MRI suggest implicitly that this ambiguity over MRI's user group was not primarily an uncertainty as to who was to exert professional control over technology, but rather an ambiguity regarding which gaze should be predominant in the cultural definition, use and further development of MRI. My interpretation is that MFR's establishment of the evaluation goals as clinical with radiology as its "normal" professional home, and of other research as experimental (important but less acute) strengthened a loose link between the available MRI technology and one of its candidate uses: the clinical, radiological gaze. The association that was created by different actors (applicants, MFR, UAS) between the clinical and researchers' position as qualified users, and between the experimental and researchers' position as developers, was a further specific configuration of meaning around MRI: the radiological gaze needed users and the laboratory gaze, developers. This configuration was not cemented, but contributed to the hierarchies of visions about MRI—the publically funded clinical radiological gaze required clinical users, radiologists.

What else did MFR's decisions imply? As the rest of this dissertation will show, there was more to the line that was drawn between clinical and experimental than a distribution of funds. That line created different initial conditions for two visions of *what* MRI would primarily do: produce images of the body as an integral part of radiological clinical practice, or explore the possible development of alternative representations of different processes in the body.

The formulation of applications and the assessment thereof were concrete moments in which meanings about MRI were generated. Wetterberg's moral arguments in the media about the urgency of acquiring and using MRI, Scherstén's statements that MRI would be broadly purchased and used if no public control was established, and the scenarios of diffusion put forward by Hemmingsson and Wetterberg performed a modern medicine's technological imaging imperative: If imaging NMR was available abroad, Swedish medicine could not just stand outside and watch others' NMR images.

The further diffusion and use of MRI outside the control of the authorities suggests that these initial conditions were not determinant as regards the directions of technomedical exploration of MRI in research practice, even though the clinical use of MRI in the 1980s was predominantly radiological. Furthermore, that diffusion suggests that the technological open-endedness of MRI endowed it with a form of plasticity that enabled different medical specializations to pursue their own visions of the MRI gaze in their own research settings. Consequently, my task in the following Chapters 3 through 6 will be to analyze more closely the visions and methods at work in MRI research. To start with, the next chapter will address how MRI "went radiological" in practice.

interlude

MRI metaphors of display

Figure 4. Hall at Karolinska University Hospital Huddinge. Photo: Isabelle Dussauge 2008.

In Swedish clinics and media, an MRI scanner is commonly referred to as a "magnet camera" (*magnetkamera*) or "MR camera" (*MR-kamera*) (44 500 hits on google.se) or "magnet roentgen" (*magnetröntgen*) (31 000 hits).[1]

The name "magnet camera" is not altogether surprising if we bear in mind that X rays were considered "a new kind of photography" in the years that followed their discovery.[2] In other words, radiological technologies were not unusually seen as in the lineage of optical technologies: photography and film.[3] It is plausible that Stockholm psychiatrist Lennart Wetterberg—the main protagonist of Chapter 4 in this dissertation—coined the term "magnet camera" in the early 1980s; the origins of the term are however less important here than its wide popularity. The designation "magnet camera" has been used by lay persons and specialists, in public and scientific contexts. Not least, it has penetrated the world of the hospital: As Figure 4 shows, the major Karolinska University Hospital Huddinge in the region of Stockholm directs patients to MRI examination rooms with a sign that reads "MR-kamera".

Cameras refer to our need to see—but not only to see: cameras are rather about looking, peering, showing. Consider the titles of scientific publications such as "The magnet camera sees more than the surgeon", or "Fetal anatomy revealed with fast MR sequences":[4] The seeing at stake through MRI as camera is an active seeing, the revelation of objects deeply buried in the obscurity of the living body, the dispelling of our ignorance of them and their exposure to the outer light and to display for public scrutiny.

In the history of anatomy and of the clinical gaze as told by Michel Foucault, this act of display is crucial: dissection—the opening up of the corpse—as a new source of knowledge, affects the significations of life, death and disease, the clinic's very frames of knowledge, and the interplay between visible and legible, between object and subject. Displaying as a structure for seeing is thus highly significant. In *The Birth of the Clinic*, Foucault repeatedly comes back to metaphors of light and darkness; life, taking place within the body, beyond the realm of visual observation, is confined to night or darkness; whereas death, enabling the body's dissection, casts its light upon the inner body made visible and legible to the observer.[5]

"Magnet camera" realizes a consensus between medical and popular meanings and crystallizes a metaphor. The immediate content of the "camera" metaphor refers to the ability to show something in images—creating visual proofs of a reality "out there". It also emphasizes the ability to display rather than the seeing, and carries the idea of a technologically produced vision which discloses something hidden in the darkness of the body.

Similarly, *roentgen* in "magnet roentgen" leads the meaning of the MRI gaze towards radiology's in-depth vision and its threat of bodily intimacy. Using of the name "magnet roentgen" assimilates MRI in radiological culture, in Sweden still much referred to as "roentgen" with its "roentgen doctors". X rays stand for particular powers of visual penetration enabling us to see the body under the skin—with radiation rather than light.

The piercing powers of MRI and radiological technologies—i.e. their ability to perform a sort of dissection *in vivo*—meet those of the endoscope (a small fiber optic cable connected to a camera inserted into the body through a hole) in a somehow peripheral but popular topic: mummy imaging. A few articles of a kind recurring in the popular science magazine *Illustrerad Vetenskap* ("Illustrated Science") tell the story of mummies examined with an unspecified scanner—most probably CT.[6] Scientific publications have also reported such interventions and the use of endoscopy (to provide images or tissue samples) on mummies.[7] What for? The purpose of these examinations was to view the inside body of the mummy, or what remained of it, for the purpose of identifying which death rituals including the removal, cleaning and replacement of organs had been performed on the body mummified. One mummy, Lady Tashat's, was the first to be examined with MRI. Consider the way this is described in a scientific publication from 1986:

> [The mummy] of Lady Tashat [...] was examined by MRI to see if residual moisture might still be contained within dehydrated structures. This XXVth Dynasty (715-633 B.C.) mummy was flown by private jet from Minneapolis to Rochester, MN, and was transported to St. Mary's Hospital, where she became the first Egyptian mummy to undergo MRI. Her mummy, contained within a beautifully painted cartonnage [...], was placed into the Picker International 1100 resistive MA scanner. [...] the body coil was used for all scans [...].[8]

Lady Tashat's mummy is taken care of and talked about as if it were Lady Tashat herself (her living body), which is reinforced by the inclusion of a photographic portrait of Lady Tashat's mummy (her sarcophagus) in the article. MRI was thus tested for mummy-peering on Lady Tashat's mummified body; and proved worthless since mummies are as dry as anything can be.[9]

Mummies and the attempts to visualize their insides with radiological tools provide a significant metaphor: radiological devices embody a utopian "see-through" device that would reveal the mysteries of the body inside to the outside world—without physically encroaching on it. In contrast, the endoscope had to be inserted through existing cracks, or required a hole to be drilled if the mummy was well preserved.[10]

Although long dead, mummies work as a metaphor for the living human body: "opening" them to see their inside would destroy them. In twentieth-century Western medicine, opening the body's outer layer to see inside it was synonymous with dissection, autopsy, corpses subjected to scrutiny "in the bright light of death".[11] And in the mummy's inner body it is its history that archeologists look for, just as the autopsy of a corpse was pathological anatomy's tool to track the signs that disease had imprinted in the body. Radiology with CT (maybe MRI; earlier, X rays) literally gave mummies an inside body and became science's missing sixth sense to pierce through the opacity of history.

[3] going radiological

making MRI a tool for radiological vision

MFR's early decisions, and to a certain extent, the decisions of the Uppsala NMR group, directed MRI towards radiology's institutions, where MRI's vision was to expand: clinical work and research in the radiology departments, authorities' regulation of the diffusion of medical technology, and ultimately radiology's gaze upon the body.

But these early decisions cannot explain MRI's later trajectory. I want to suggest that the crucial aspects of the introduction of MRI did not concern how many actors acquired the technology and when, but rather how MRI was made to see what these actors attempted to make visible. These processes of shaping the MRI gaze were by no means simple, and often convey the feeling that early MRI users were working in the dark when trying to make certain kinds of bodily objects or bodily information intelligible and visible with the new technology. Chapters 3 through 6 address the formation of configurations of the MRI gaze in three different contexts. Whereas the next chapters will focus on psychiatry and the laboratory, I begin here with the shaping of MRI's visuality within the radiological gaze.

This chapter aims to show how early MRI users recurrently made MRI radiological: clinical, anatomical and visual in specific ways. I focus on the processes by which MRI technology became a part of radiology's clinical vision, as the result of active discourse production and technomedical practice. As the period of time under scrutiny here (roughly, 1984—1990) is short, this chapter is organized thematically rather than chronologically.

In a first section, I show that MRI researchers (radiologists, physicists, psychiatrists) evaluated MRI within the frame of existing radiological technologies, and I analyze their main arguments about the scientific-medical value of MRI. In the second section of the chapter, I will show that the MRI gaze that was constructed and used by radiologists followed the principles of clinical radiology's gaze. In a third section I will outline examples of the development of radiological tools for MRI on the ambiguous (quantitative/visual) basis of MRI representations.

EVALUATING MRI REPRESENTATIONS

The official evaluation project aimed at assessing MRI's clinical value to Sweden and the national need for the new technology; and it was highly inconclusive: Sweden's need for MRI could not be identified in 1986, nor in another, Scandinavian, study in 1987.[1] Nevertheless, the evaluation's rhetoric of containment fueled quite a few articles written by Swedish radiologists and physicists working with NMR/MRI. At the same time as its material expansion was subject to attempts at containment, MRI was the object of a discursive explosion in the Swedish medical journal *Läkartidningen*, and elsewhere.[2]

Many of the arguments in these debates about whether MRI was a good investment for Sweden or why this should not be an issue in the first place were based on the expected financial effects, costs and benefits, of the technology. Although these explicit debates focused on the effects of MRI from the point of view of health care economics, MRI's value was established on the basis of what it could *show* (i.e. which representations it could produce), which in turn was not interpreted in a void but in the constellation of available medical imaging technologies and the representations provided by those. Which were the main scientific arguments put forward in favor of MRI? *What* in NMR representations was considered of value?

valuably novel as better and unique

Stuart Blume emphasizes how MRI was from its early years systematically compared to CT in terms of what the technology could show and how well. Blume writes: "The studies largely focused on comparison of NMR with CT scanning [...]; that is, the evaluation assumed that assessment of MRI is to be in terms of its place in radiological practice."[3] In his interpretation of the controversial evaluations of NMR conducted in Britain in the 1980s, Blume argues that MRI landed under the authority of radiology; further, he points out that radiology was never a granted home discipline for MRI since it was highly unclear who – of pathologists, chemists, radiologists, or physicists – was MRI's given target group. Against which gaze was MRI valued in the Swedish evaluation, and how?

The Swedish evaluation project was located in Uppsala, but the evaluation report published by SPRI in 1986 included experiences from several Swedish and Scandinavian sites that had a commercial MRI device (which excluded Persson's group in Lund from reporting "medical experience" of MRI). In Uppsala, MRI was tested clinically on patients' heads and bodies (about 50-50%); from St. Göran's Hospital, it was mostly examinations of the brains of the patients that were reported, although many other bodily examinations were performed.[4] Many of the researchers who reported experiences of MRI to SPRI were radiologists, but physicists, chemists and psychiatrists were also represented. However, most of the Swedish evaluation and of the research articles published in *Läkartidningen* in the 1980s were based on comparisons between MRI images and available imaging technologies: CT, PET, X ray, ultrasound imaging, etc.[5] The set of all these technologies thus provided the context within which the MRI gaze was conceived of in the evaluation. For example, neuroradiologist Kjell Bergström, radiologists Uno Erikson and Anders Hemmingsson, and physicist Bo Jung wrote in 1984:

> Its [MRI's] position in relation to other imaging technologies, mostly X ray CT, is still unclear in many respects. The pros and cons of MRI in comparison with other methods are the object of continuous assessments.[6]

This set of existing imaging technologies and the representations they produced also defined the scope of the radiological gaze in the 1980s; it defined what could be seen and what could not.[7] For instance, radiologists

Sven Laurin, Holger Pettersson and Jonathan Williams wrote in an article about what MRI could achieve in radiological examinations of children in 1985:

> The intestinal peristalsis and the respiratory movements cause the ventricle, the intestinal canal and the pancreas to be much less visible with MRI than with CT. [---] On the other hand the liver and spleen are depicted as well with MRI as with CT. Some liver conditions like hemosiderosis and fat storage are well visible with MRI.[8]

What was valued in MRI representations was on the one hand, what it could show *better* than existing technologies, and on the other, what it could show that the others could not—what was *unique* to MRI. This is illustrated by the following quote from the official evaluation report from SPRI, in which I have added the notations "MRI IS BETTER" and "MRI IS UNIQUE":

> This relatively quick spread of a costly technology is often attributed to the fact that it is a practically risk-free method, at the same time as it makes it possible to obtain anatomical information which is difficult or impossible to obtain with other methods [MRI IS UNIQUE!]. [---] At present, the MRI technology complements other diagnostic methods [MRI IS UNIQUE!], but it is expected that it will also be able to replace some of the radiological methods in use now as experience [of MRI] increases [MRI IS BETTER!]. Moreover, MRI is expected to cover certain totally unique diagnostic fields [MRI IS UNIQUE!].[9]

A first major aspect that MRI researchers argued made MRI a *better* technology than other imaging devices was that it *made visible* the anatomy and pathological anatomy of even small structures of the body.[10] In that sense, what made MRI a better technology was that it could show structures that others left unseen—in the following example, small structures in children's small bodies:

> The blood vessels of the abdomen are much more visible with MRI than with CT, and the difference [between what these two technologies show] is more noticeable the smaller the patient. Thus the renal veins and the intestinal veins may be seen clearly, like their corresponding arteries. The vessels and arteries of the pelvis and the femoral vein are visible even in newborns.[11]

Similarly, SPRI noted in their 1986 evaluation report that "because different kinds of tissues can be distinguished in the pictures, the salivary glands and changes in those can be clearly defined from the surrounding structures"; and that "further, the vocal cords and the inner structures of the epiglottis can be better imaged" with MRI.[12]

Specific pathologies that were previously out of radiologists' reach became visible with MRI. An important example was multiple sclerosis: "We have by and large not had any possibility of morphological diagnosis for inflammatory processes like multiple sclerosis, MS," a group of radiologists argued in the mid-1980s—then adding: "With MRI it is possible to demonstrate MS plaque within the spinal cord."[13]

The detailed MRI anatomy of the spine, bones and muscles opened a new visual space in which doctors could hope to elaborate new understandings of diseases.[14] This new visibility of radiologically hidden structures—in part attributed to the high *contrast* of MRI images—was also put forward by MRI researchers as an advantage of MRI in tumor diagnosis, as it gave MRI its ability to define tumors better than existing technologies (mostly CT, ultrasound imaging and X ray angiography). For instance, different articles listed that "MR can often give more information than computed tomography, partly through [---] its high contrast"; and that the "extraordinarily high contrast resolution implies that the soft tissue tumors can be defined more exactly than before and their relation to neighboring muscles, skeleton, vessels and nerves can be determined. This implies that angiography is in many cases no longer necessary".[15] Further, MRI could achieve and surpass other technologies' powers of contrasted vision without the injection of contrast agents for certain examinations: "The excellent contrast resolution that MRI gives is its foremost advantage for the examination of the skull. It is possible to visually separate different kinds of pathologically altered tissues without using intravenous contrast agents [...]."[16]

These examples reveal that the system of practice and visualizations within which MRI images were compared with other technomedical representations was pathological anatomy's clinical gaze: a gaze that defined anatomical lines, separated adjacent tissues and strove to isolate the pathological from the normal for diagnostic purposes.[17]

Other arguments declaring MRI a *better* clinical instrument and a welcome replacement for existing methods were that MRI reduced examination discomfort or pain for the patient, and that MRI was a risk-free technology since it did not use harmful radiations such as X rays. [18] MRI was also better than CT for imaging of certain regions of the brain where the skull's bony mass introduced distortions in the CT scans (CT was based on X rays, which were sensitive to bone).[19] Another recurrent argument was that MRI enabled imaging in any spatial plane (producing "slices" along any angle) due to the spatial encoding of the signals on which MRI images were based.[20] This latter property overcame the limitations of other imaging technologies like CT where images could only be obtained along certain given angles.[21] It is as though MRI extended radiology's gaze deeper within the body and made radiology's utopian transparent body really transparent: visible from any spatial point of view.[22]

Interwoven with such arguments—which presented MRI as a *better* technology—was a second string of discourse which described MRI as *unique.* The *unique* MRI gaze was based on the novel kind of signals that MRI's apparatus produced and analyzed in producing pictures. The *unique* MRI gaze was novel and groundbreaking: it was acknowledged by grand formulations such as "a new dimension in diagnostic radiology"; "new diagnostic imaging method with great possibilities", "great diagnostic possibilities".[23]

The hopes placed in MRI's unique information were focused on tissue analysis and tissue identification from the early eighties onwards. The utopia projected in the early articles on MRI was that of an *in vivo* chemical analysis (*in vivo* meaning performed in the living body): an analysis of the metabolism, chemical composition, physiology and cellular biochemistry of tissues—all of it expected to be available within half a decade:

> [MRI] should be understood as having a great diagnostic potential. In addition to morphological information [information about the shape of the tissues], it can also provide information on cellular chemistry and physiology. NMR should have become a clinical method within the next 3-5 years.[24]

But the authors of such articles on MRI usually added caveats about how little way along this utopian road of development the technology had so far traveled—for instance, the enthusiastic text quoted above was eventually qualified by the following: "However, no "chemical" pictures of clinically acceptable quality have yet been demonstrated."[25]

Soon, the idea of an MRI-based, visual and non-invasive total analysis of bodily chemistry was backgrounded as a dream for the future, and instead the more realistic hopes of tissue characterization through proton imaging (i.e. the imaging based on the properties of bodily water only—oblivious of chemical compounds other than hydrogen) took the foreground.

MRI researchers emphasized their hopes that MRI's specific kind of information could improve tumor diagnosis and tumor characterization—consider for instance this excerpt:

> Interesting results can be expected from MRI's unique capacity for tissue characterization. We have [...] observed different signal intensities from a [tumor] after radiation therapy depending on whether it is composed of fibrosis or of remaining viable tumor.[26]

Although tumor differentiation and characterization posed considerable difficulties and would never reach the definitive diagnostic power MRI researchers hoped for (see Chapter 6 in this dissertation), tissue characterization was successfully used as a way to create a visual separation between different kinds of tissues on MRI scans:

> MRI provides a tissue characterization which has not been possible with the [other imaging] methods available so far. Different kinds of normal tissue—e.g. gray and white brain matter, kidney cortex and medulla—can therefore be separated on the basis of different MRI characteristics. Moreover, the different components of tumors—active tumor, necrosis [dead tissue], edema [accumulation of fluid]—can be studied, and MRI has a high sensitivity to e.g. inflammations [---]. MRI has thus been shown to be of great value in the assessment of tumor expansion in the brain [...], hypophysis, mediastinum and abdomen.[27]

But on the whole, even that more realistic goal of visual tissue separation and tumor characterization/identification was still being depicted as a hope for the future, a potential, rather than a result or a possibility in the present. In 1985, radiologist Holger Pettersson wrote that "Tissue characterization with MRI, i.e. the identification of a tumor through its relaxation times (T1 and T2), is a method that is still in its infancy",[28] and in 1987, that "additional method enhancement is expected within the field of tissue characterization, with the development of new pulse sequences [---]. This will give increased knowledge of the physical-chemical properties of e.g. normal tissue as opposed to tumor tissue."[29]

The contrast between the established value of MRI and its potential was striking, as the following excerpt suggests:

> The expansion of the skeletal tumors in the soft tissues can be better seen with MRI than with CT [...], and the extent of the tumor within the bone can be determined more exactly [with MRI] than with any other method. [---] The different relaxation times of the tumors give a possibility of tumor differentiation, which is however complex and demands further research.[30]

Whereas the *superiority* of MRI, based mostly on its powers of anatomical discrimination, was being established in practice and recognized as such by the mid-eighties, its *uniqueness* in terms of tissue characterization was mostly imagined as a promising horizon, towards which medicine would be expanding in the future.[31] In contrast to the *better* MRI gaze which was recognized as already clinically useful and motivated, the *unique* MRI gaze was mostly the object of futuristic descriptions and attempts without clinically convincing results.

And even the uniqueness of MRI was valued within the frame of the existing set of radiological technologies. This is illustrated by a recurrent metaphor for the role that was attributed to the MRI gaze in evaluative descriptions: MRI technology "filled gaps" in the radiological gaze (e.g. MRI "fills earlier gaps in the diagnostic arsenal and its medical value is appreciable").[32] In other words, MRI expanded the radiological gaze on the basis of its particular characteristics, which were different from those of established radiological technologies.

In the Swedish evaluation project, the radiological gaze—its existing imaging technologies and its visual principles being those of pathological anatomy—was thus the main reference frame of the evaluation. Other interests in the novel representations were given some space—but a mostly expectative space.[33] MRI enhanced and complemented the apparatus of the radiological gaze. My analysis of the scientific arguments produced in the evaluation of MRI shows that the new technology was interpreted in the frame of radiology's existing gaze: imaging technologies and representation practices. Within that frame of comparison the valuable novelty of MRI was conceptualized as superiority and uniqueness, of which the latter was given less immediate importance than the former.

MRI AND BODY IN SPACE AND TIME: COMPOSING A RADIOLOGICAL GAZE

How was vision with MRI constituted *in practice* within the frame of radiology? As the previous section has shown, MRI was assigned an ambiguous position in radiology's technological arsenal: it was considered as one among several radiological imaging devices, and at the same time, acknowledged as a quantitative-molecular technology working to its own physical principles. This opened for two main kinds of configurations of the MRI gaze: one aligned with a radiological gaze, and the other aligned with a laboratory gaze. The emergence of an MRI laboratory gaze will be treated in Chapter 6. Here I want to explore how MRI was early made to align with the radiological gaze: radiology's practice and representations.

This section is based on an analysis of a selection of scientific publications by radiologists in the 1980s. It focuses on two examples and makes the point that MRI's technological apparatus was developed in line with the fundamental principles of the radiology gaze.

recomposing radiology's anatomical bodily space

In the previous section I have analyzed how MRI images were valued by MRI researchers. However, what I call the MRI gaze was made not only of images or representations. MRI scans were but one element in the MRI gaze; the modes of vision enabled by MRI were also literally embodied in its *material* apparatus. Whereas the most visible part of the MRI apparatus was the bulky scanner part (the "tube" into which the patient's body was shuffled), most radiologists conducted imaging work using smaller radiofrequency *coils*. Coils were an early extension of MRI's technology-body apparatus that intensified the MRI signal around a certain focal point of the body. Coils acted as local receivers or transmitters of MRI signals, and enhanced the intensity of signals (and therefore, of images) of the body's region in the center of the coil. Coils were loose parts of MRI's apparatus; they were connected for the examination, placed on or around the body, and removed and disconnected after examination. In other words, coils were a materially fragmented extension of the technology-body apparatus.

I want to dwell on how coils inform us about the technological visuality that radiologists performed with MRI in the 1980s. Coils are an interesting object of inquiry for the historian looking for the material practice of imaging. Although far less the object of publications than, for example, pulse sequences (the "programming" of MR images), coils were ubiquitous and crucial in MRI imaging: it was through coils that the electromagnetic signals of the MRI scanners and the examined body were transmitted and received. In an MRI examination's chain of events, coils were literal mediators—the material instances through which bodily-molecular phenomena were translated into electrical signals to be handled downstream by the MRI machine.[34] MRI researchers also expected the development of coils to bring major improvements in MRI's vision.[35]

Here I will briefly analyze a project conducted by Lund radiologist Elna-Marie Larsson and her colleagues on the optimization of the use of coils. My purpose is to understand how their early exploration of the clinical usefulness of MRI went together with an optimization of the MRI gaze according to the principles of radiological vision. Larsson and her colleagues worked on the optimization of coils for the MRI scanner of the department of diagnostic radiology at Lund University Hospital. The issue she addressed was clinical: Radiologists using MRI for examinations of the spine had access to a range of coils with different shapes and properties, but no stable criteria had been established that would match a given spinal region to be imaged with a given kind of coils.[36]

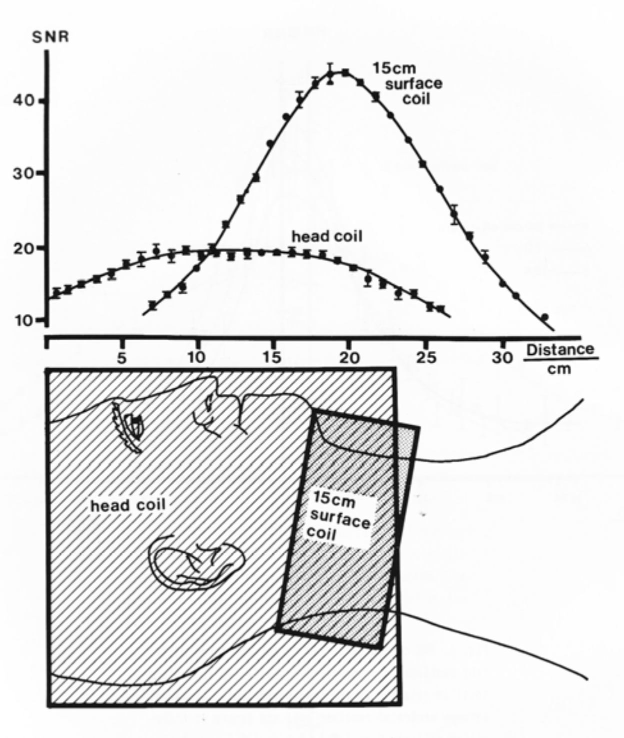


Figure 5.
Characteristic plots obtained with two different coils (head coil and surface coil), with depiction below of the coils' spatial position in relation to the body.[37]

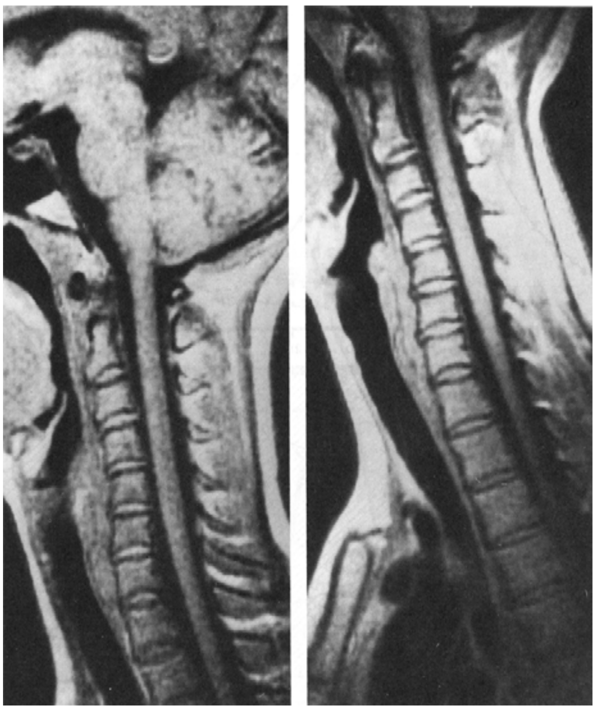


Figure 6.
MRI images of the spine, obtained with two different coils (head coil on the left, surface coil on the right).[38]

Coils were made of metal (and a coating material around it), and could come in a range of different shapes and sizes: they could for instance form a helmet into which the patient's skull was introduced ("head coil") or be shaped like a soft, flat loop that was placed upon a region of the body ("surface coils"). Such coils were placed directly onto a body part of the patient or wrapped around it just before examination. The patient's body would then be examined, coil on, in the MRI scanner. (A head coil can be seen in Chapter 4, Figure 12.) A component of the tube of the MRI scanner could also work as a built-in "body coil". (There were also more specific coils not used in Larsson's study, such as "eye coils" which were made of a flat ring that could be placed around the eye).

Although her problem was defined as clinical, Larsson's approach was experimental: it was the coils themselves that she aimed to characterize. Larsson imagined devices to quantify the spatial performance of different coils: The coil would be placed around a test object of known NMR characteristics (a tube filled with water, and a "human-like plastic phantom"), and the intensity of the image/signal received by the coil was measured as a function of the observed volume's (pixel) distance to the coil center: The further from the center of the coil, the weaker the signal. Coils were thus made to exhibit specific profiles that differed as to how strong the maximum intensity was, and how quickly the signal/image deteriorated outside the centre of the coil. Larsson expressed the *results* that characterized each coil's vision with different forms: graphs and MRI images. Examples of the results are reproduced in Figure 5 and Figure 6.[39]

The curves reproduced in Figure 5 show a quantitative profile of two coils' focus and the deterioration of each coil's vision with distance from their center. A human body (or the dummy used as phantom for the study) is schematically depicted under the curves, and provides spatial landmarks which function as a context for the quantitative values of the MRI signal. These curves work as an experimental map of the vision of the coils and define clear spatial limits to the powers of vision of the MRI coils. Most striking is the curve on the right (standing for a "15 cm surface coil"); its high maximum and the steep decrease around it suggest a powerfully focalized vision. In contrast, the curve produced for the head coil, on the left of the graph, is flatter and suggests a more even field of vision. Other graphs, which are not reproduced here, plotted the profile of other coils for the rest of the spine in a similar manner. On the basis of this phantom study, Larsson predicted which coil should be used for imaging of each part of the spine (e.g. head coil for upper spine, surface coil for the junction between the skull and the spine, and body coil for a middle region of the spine).

Corresponding MRI images were produced and published, two of which are reproduced here as Figure 6. Two MRI images obtained with the two coils characterized in Figure 5 were displayed next to each other. Each image in Figure 6 depicts a part of a volunteer's spine as a side-on vertical section. The picture on the left displays the lower part of the head, and, below, the upper part of the spine. The picture on the right displays less of the head and a larger part of the spine. Metaphorically, these two MRI images look as if a flashlight has been directed onto a smaller region of the open body, leaving its surroundings in the shade; the left image gives a sense of a more even exposure to a less sharp light. Figure 6 illustrates the fact that the MRI gaze as produced with coils was a "focal gaze": the images are clear in a highly localized portion of the head or neck, and dark and blurred above and below.

In Larsson's work, these MRI images functioned as an *in vivo* verification of the experimental, quantitative results obtained with the phantom. She was thus able to confirm the predictions she had formulated with the phantom measurements, and to propose that such experiments be systematically used for assessment of future coils.[40]

What interests me here is to understand what these coils did—if we go beyond their technical description? I have said and illustrated that coils created a visual focus by intensifying the MRI signal around a certain point of the body. However, not only were the physical signals intensified, but also MRI's gaze. The more the MRI gaze was focused on a given "region of interest" (for example, the spine at a given height), the less it saw of the surrounding flesh. What was activated by coupling and materially placing coils within the technology-body system was thus a discrete system of separate and loosely attached focal MRI gazes.

Amit Prasad has shown that the radiological gaze enacted through MRI with diagnostic purposes is "bifocal". This means that the MRI gaze organizes and performs the relation between the part (e.g. organ, tissue) and the whole body: the diagnostic MRI gaze both focuses on separable parts *and* re-situates them in a whole-body system on a visual basis. I want to argue that the use of MRI coils may then be understood as a material-technological expression of the imperative of separability characteristic of the radiological gaze: i.e. the possibility to work with body parts "as though [...] body parts were disjoint and isolable from each other". This separability is a precondition of the gaze's bifocality, as Prasad argues: "The radiological gaze of MRI [...] has a 'bifocal vision'. The [...] analysis of [...] MR images in the radiological laboratory is limited to focusing and visually extracting particular anatomic details that can be useful in detecting [...] pathology. Radiologists are not interested in deciphering the anatomic details of the body [...] completely. Yet this focusing is possible because of the visual training of radiologists in understanding and interpreting the anatomic details of the whole body."[41]

Thus the disjointed MRI hardware—coils—fragmented the MRI body further into a discrete anatomic space made of visually separated bodily regions. The bifocal MRI gaze always re-situated representations of body parts within the whole body: it decomposed and re-articulated bodily space in practice along a fundamental principle of anatomy's geography and radiology's visuality.

articulating bodily space on clinical time

Coils and resulting MR images signified a specific, bifocal clinical-radiological visuality; yet it would be a reduction to view the MRI gaze and radiology's clinical anatomic gaze as entities conceptualized only in space. Michel Foucault has shown that the anatomo-clinical gaze realized the integration of anatomy's *geography* of the body with the clinic's *history* of the disease (the clinician's analysis of temporal series of symptoms). From the early 19th century onwards, medicine's dominant understanding of the body has been one that related bodily space to pathology's clinical time: the time which had to elapse between examinations of the patient for doctors to observe *visible* pathological changes in the patient's body.[42] Here I want to analyze how pathology's clinical time was made part of the MRI gaze in the early radiological practice of MRI.

MRI has been used clinically since commercial MRI scanners became available in Sweden's university hospitals in 1984 (cf. Chapter 2 and 4). For radiologists and other specialists abroad and in Sweden, MRI was by the mid-eighties considered a clinical success in diagnosis of lesions in the brain and spine; for instance, Elna-Marie Larsson wrote in an article in 1988: "Magnetic resonance imaging (MRI) has proved to be exceptionally useful in the evaluation of spinal pathology", referring to a range of publications from 1984-1987. The integration of MRI in clinical radiology was a mutual process: MRI's new images affected radiology, and reciprocally, clinical information provided the context in which MRI scans were intelligible.[43] I will here use this example from Larsson's work on MRI of the spine after the mid-1980s, and analyze how she actively correlated MRI to clinical settings and time when attempting to define MRI's role in clinical practice.

This project in Larsson's research aimed to identify what MRI could actually *show* in the spinal cord, and to establish how accurate (and clinically useful) that information provided by MRI was. The study was conducted on patients among whose symptoms were back pain and

Inflammatory lesions

Case No.	MR diagnosis	Final diagnosis
7	Discitis C4–C5 with epidural and paraspinal abscess and cord compression, Fig. 3	Discitis with epidural and paraspinal abscess and cord compression (needle aspiration, bacterial culture, clinical course)
8	Cervical myelitis	Myelitis (CSF analysis, clinical course, repeated MRI)
9	Cervical myelitis, Fig. 4	Myelitis (CSF analysis, clinical course, repeated MRI)

Figure 7. Example of comparisons between MRI-based diagnoses and "final diagnoses" in the study conducted by E.M. Larsson et al.[45]

impairment of sensory and motor functions, which were preliminarily interpreted as symptoms of lesions of the spinal cord.[44]

Figure 7 shows one table of results of Larsson's study; it also provides a summary of the procedures used in the study. For each patient, MRI scans of the patient's spinal cord were taken, and an "MRI diagnosis" was formulated on the basis of the interpretation of the scans. These results are reported in the second column of Figure 7. Each patient was then submitted to other medical examinations, involving methods such as radiological examination, laboratory tests, clinical examination, surgery or autopsy (these methods are mentioned in the third column of tables of result such as Figure 7). On the basis of these further examinations, a "final diagnosis" was formulated, i.e. an unambiguous diagnosis (a "closure on pathology" in Amit Prasad's words).[46] For each patient the first MRI-based diagnosis was then compared with the final diagnosis. Where the first MRI diagnosis was in agreement with the more certain final diagnosis, the information provided by MRI scans was said to be correct. For the kinds of pathology where MRI scans had failed to identify the "true" pathology (as defined by the "final diagnosis"), MRI was thought to be of limited clinical use.

This allows two comments. First, for each patient case, the MRI diagnosis, i.e. the first interpretation of MRI scans, made sense only within the range of existing diagnostic methods that encompassed much more than just radiological imaging: for instance laboratory tests and clinical observation.[47]

Second, in two cases described in Figure 7 (Cases no. 8 and 9), the methods used to make a final diagnosis include "repeated MRI". This means that in order to establish the "final diagnosis", new MRI examinations of the patients were conducted some time after the first MRI scan. Larsson's publication described what she and her colleagues observed by comparing these "repeated MRI examinations" with the initial MRI examinations. Consider the two following examples:

> Following treatment with antibiotics for one month, MRI revealed that the signal intensity in the intervertebral disc had returned to normal. Only small remnants of the abscesses were seen.
>
> ---
>
> On MR examination after 12 weeks and 4 weeks, respectively [for two different patients], spontaneous resorption [i.e. healing] of both haematomas was seen to have taken place.[48]

The quotes above illustrate that radiologists used MRI as a window to follow the evolution of pathological-anatomical signs. In the first example the second MRI scan was taken after antibiotic treatment. A comparison with the previous MRI scans showed a change in the diseased part of the spine: where MRI signal intensity was previously different from the rest of the spine, the new MRI scan showed an intensity "returned to normal". Clinically, this was taken as proof that the treatment had had a positive effect on the pathology. The concluding formulation of this case, "Only small remnants of the abscesses were seen", induces the feeling that the researchers had been peering into the body, looking for small remainders that the disease would have forgotten on its way out of the body. The MRI scans worked as "before" and "after" snapshots of a specific part of the body.

The second example quoted above deals with two patients. New MRI scans of these patients' spines had been taken a few weeks after the initial MRI examination. Although no treatment had taken place, the new MRI scans indicated that the pathology in these patients (haematoma) had disappeared. Here also, the comparison of MRI scans between which a few weeks had elapsed was used to establish the changes in the patients' pathology. Moreover, the new MRI scans were not only compared with the previous MRI scans, but also systematically correlated with the patient's "clinical course" (cf. third column in Figure 7), i.e. the evolution of the disease as established by clinical observation of the patient's symptoms. My interpretation is that the MRI gaze was thereby calibrated on the disease's clinical course by establishing the MRI differences in time in the same patient: changes in MRI intensity were established as a measure of pathology's changes in the patient's anatomy.

In other words, the MRI scans were made to track marks imprinted by disease on the spinal cord. What MRI displayed there was not disease in-the-making—pathological processes as they happened—but rather the marks or footprints imprinted in the body by pathological changes. The body as a conceptual system produced with MRI was therefore held together by implicit causality principles belonging to the anatomo-clinical tradition's conceptions of pathology: disease phenomena altered the flesh in ways that left footprints which could be detected with MRI and used as signs to identify (diagnose) the disease.

I want to argue that repeating MRI, with a few weeks' interval, and correlating the interpretation of the MRI scans with the results of other diagnostic methods and observations of the patient's clinical course was a way to test MRI's capacity to align not only with clinical diagnosis, but also with clinical course and thus with "clinical time"—the time necessary for pathology to imprint marks into the body, and for clinical interventions to change these marks. Pathological life and its abstraction, clinical time, were then what held subsequent MRI pictures together: what organized their meanings relative to each other and to other clinical results. The example of MRI research that I have studied here shows that clinical testing and clinical integration of MRI made radiology's clinical time part of the MRI gaze.

As a whole, the two parts of this section have described the making of a radiological anatomical MRI gaze in practice along two lines: First, radiologists produced an MRI-mediated anatomical body, approached in its spatiality through radiology's visual modes of knowledge which produced the body as a set of separable, localized solid parts and tissues. Second, radiologists articulated this anatomy's spatial gaze on the time and causality principles of the clinical gaze. The clinical introduction of MRI (and the related technomedical developments of MRI in clinical practice) thus recapitulated aspects of an earlier history described by Foucault: that of the formation of an anatomo-clinical gaze.[49]

WORKING WITH IMAGES IN THE BORDERLANDS OF THE RADIOLOGICAL GAZE

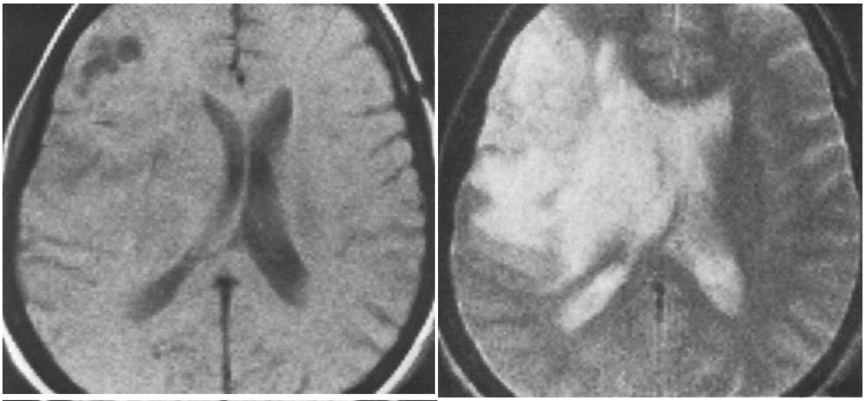
At the heart of the exploration and development of MRI as a radiological tool lies a paradox—as the above has demonstrated: Whereas the information carried in MRI signals was recognized as the source of MRI's unique properties and potentialities, MRI images were aligned with radiology's gaze and visuality as performed by existing imaging devices such as CT. Here I want first to add a last element to the claim that radiologists integrated MRI in radiology's visuality, by outlining how traditional radiological methods such as subtraction and contrast agents were developed in MRI-specific versions. I will then qualify that claim by exploring a sample of the quantitative and experimental methods with which radiologist Anders Hemmingsson's group explored the space of MRI representations.

radiological methods for a quantitative-visual technology

I have already presented two ways by which researchers made MRI radiological: evaluating it as such, and reproducing radiology's visuality and clinical time. This section presents a third aspect of the radiological integration of MRI: Radiologists involved in MRI research devoted many of their efforts to enhancing MRI images by developing traditional radiological methods for MRI. Two such methods were *subtraction* of images, and the use of *contrast agents*. Image subtraction and contrast agents were two common radiological methods which increased the *contrast* in radiological images, and therefore enhanced the visual separation or isolation of bodily structures. Here I will outline these developments and discuss how they influenced the MRI gaze.

Whereas the evaluation project at UAS (1984—1986) involved clinical exploration of MRI's value by many research groups (cf. first section of this chapter), Hemmingsson's NMR group, soon renamed MR group, concentrated their efforts on technological exploration and development of further MRI techniques. As a result, Uppsala's publications dealing with the subtraction of MRI images appeared in 1986 and 1987, among others in Uppsala Ph.D. student Karl-Åke Thuomas' dissertation.[50]

The point of departure of Thuomas and Hemmingsson's group was what they referred to as common radiological practice since the 1960s. Subtraction of images was originally a method by which one scan (e.g. X ray) of a body part would be subtracted from another similar image taken



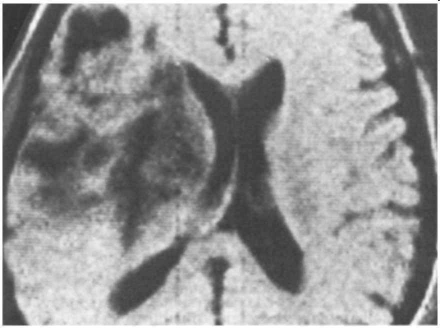


Figure 8.
Top: Two MRI scans of a patient's brain, T1-weighted (left) and T2-weighted (right), respectively
Bottom: Subtraction image of the same brain as above; displaying glioma (irregular dark structure on the left side of the image).[51]

with slightly different parameters. The resulting image would therefore display the difference between the two original images, and enhance contrast between given tissues or structures. The purpose of the early work of Hemmingsson's group on development and testing of subtraction methods for MRI was to "remove structures disturbing the rendering of the image" and to produce an "enhancement of local contrast differences".[52] Using phantom experiments, Hemmingsson's group developed algorithms based on pixel-by-pixel subtraction of images and, later on, tested those on the imaging of tumors.

A common issue for radiologists was that of discriminating between two neighboring tissues with some similar MRI properties. A clinical example cited by Hemmingsson, Thuomas and colleagues was that of MRI scans demonstrating the existence of a tumor, but on which tumor and possible surrounding edema (an accumulation of fluid in brain tissue) could not be separated. That issue was pointed out in other publications as one of the main drawbacks of early MRI techniques.[53] The Uppsala MRI group made use of one of the fundamental properties of MRI that had triggered so much interest in its early technological development: MRI scans reflected complex combinations of information about the objects examined (e.g. bodily tissues); the main characteristics that influenced the appearance (intensity) of an object on an MRI scan were its proton density and its relaxation properties. The latter were characterized with the two relaxation times named T1 and T2, which stood for how long it took MR-excited protons to return to a normal configuration (cf. Chapter 1). In MRI terms, then, bodily tissues and structures differed from one another in that they had different respective densities, and different values of T1 or T2, which constituted the basis for tissue characterization.

The two top pictures of Figure 8 reproduce the MRI images corresponding to that problem, showing two different MRI scans of the same brain (a horizontal section of the brain). A large expansion on the left half of the left picture, pressing on the ventricles (cavities in the brain seen as dark spaces on the scan) in the middle of the brain, suggested a glioma (a specific kind of tumor); the intensity of the signals displayed on the scan was mostly influenced by T1. The lesion was identified as the bright and broad white region on the right MRI scan, weighted mostly with T2. However, radiologists suspected that the white region on the T2-weighted scan was produced not only by the glioma but also by an edema. The T2 properties of glioma and edema were thought to be partly overlapping, and partly distinct. By creating other MRI scans weighted with T2 in different manners, and subtracting those from the initial T2-weighted scan, Thuomas, Hemmingsson and their colleagues were able to isolate the glioma component only (which was corroborated with a separate nuclear imaging method). The bottom picture in Figure 8 shows the subtraction image they produced as a proof of the validity of their method, in which a more sharply defined dark area stands for the glioma only. Rhetorically speaking, the researchers' argument was based on a comparison between the bottom picture and the right picture in Figure 8: by subtraction the edema was effectively removed from the MRI brain shown in the two top pictures of Figure 8.

Subtraction as Hemmingsson's group conceived of it thus consisted in producing composite images, in which the MRI apparatus was given powers of discrimination that the radiologist's eye could not alone account for. These discriminatory powers, although dependent on visual handling of data and resulting in visual displays, were entirely based on quantitative modes of knowledge derived from NMR physics and associated objects of knowledge—physical characteristics such as relaxation times T1 and T2.

Similarly, *contrast agents* were a classical radiological tool intended to enhance discrimination between tissues and Hemmingsson's group worked with the testing and development of specific contrast substances for MRI. Contrast agent technology was based on the patient's ingestion or injection of a substance that would circulate in a given organ (e.g. in the blood or in the stomach and intestines) and be visible on a radiological image. On the pictures obtained at subsequent radiological examination, the structures in which the contrast agent had been injected would then be highly visible. Some contrast agents thus made organs visible; on the other hand, other contrast agents made organs disappear on an X ray scan, which was used to remove visually obstructing structures from the picture at examination.

The interest in contrast agents for MRI was high in the 1980s, and several Swedish MRI research groups tested different substances that were thought to influence MRI signal—enhancing or suppressing it. Hemmingsson's group in Uppsala cooperated with the Norwegian firm Nycomed in conducting a range of experiments, several of which resulted in scientific publications.[54] Whereas a ferromagnetic substance called gadolinium (Gd-DTPA) was increasingly gaining acceptance as a contrast agent for MRI, Hemmingsson and others explored the possibility of using what were called "superparamagnetic particles" for gastrointestinal images.[55] Their preliminary experiments on dogs and pigs led Hemmingsson's group to the first phases of a clinical study of superparamagnetic particles as contrast agent in humans in the late 1980s.

To the best of my knowledge, the subtraction method outlined above was not broadly used outside Uppsala's MRI research group. However, both the development of contrast agents and the example of subtraction illustrate how radiologists sought to incorporate the radiological gaze's principles of practice in MRI-specific imaging techniques: Radiologists endowed the MRI gaze with powers of selective vision, steering the machine's blind electromagnetic waves to separate bodily structures from each other and to visually isolate objects of knowledge along the requirements of radiology's anatomo-clinical gaze.

signals, molecules and images: borderland models

In this chapter I have shown so far that MRI researchers' evaluation discourses and radiologists' MRI research made MRI part of the radiological gaze. However, the whole picture was not as simple. In practice, much of the MRI research that was conducted in the 1980s was multidisciplinary, as the earlier development work described by Stuart Blume had been.[56]

For instance, the core of Hemmingsson's MRI group in Uppsala was constituted by Hemmingsson himself (a radiologist), physicist Bo Jung, physical chemist Anders Ericsson, nurse Britt-Marie Bolinder and physiologist (and computer programmer) Göran Sperber. The work done by Jung, Ericsson, Bolinder and Sperber together with Hemmingsson started from Lauterbur's and Damadian's fundamental publications, and modeled the interaction between MRI signals and bodily matter. Hemmingsson's group explored through modeling and simulations different levels of MRI's mediation of bodily matter: proton behavior in tissues modeled as compartmented systems; spatial selectivity of MRI-induced magnetization processes; the dependence of signal strength on repeated MRI excitation; magnetic field-induced artifacts; fast numerical methods to calculate relaxation times out of image data; mathematical modeling of MRI signal for analysis of relaxation properties.[57]

Anatomy, as displayed by other radiological technologies, provided a relatively stable background against which MRI's referent could be established. However, radiological MRI work such as that of Hemmingsson's group also made it clear that MRI's mediation apparatus challenged this traditional understanding of the referent as anatomical. What MRI interacted with, and eventually represented, was molecular-cellular interactions for which there was no clear referent.[58]

In which ways did the MRI researchers being studied here relate to MRI's ambiguous quantitative/visual character? First of all, MRI researchers, among them radiologists, (re)produced this ambiguity in intertwining visual and quantitative methods in their MRI work. Second, this section has outlined the fact that radiological methods for MRI were developed and used at the crossroads of the visual and the quantitative, and that MRI work was performed in the borderlands of the realm of imaging and that of modeling. Classical radiological methods such as subtraction had *images* (pictures) as their basis and results—but in the realm of MRI, these methods were designed through numerical and physical work with a visual support.

I want to argue that what I have earlier called MRI's *unique* properties, i.e. the quantitative character of MRI representations, were used as a resource to make MRI work radiologically and produce a clinical visual gaze. MRI's radiological gaze was thus a highly re-composed gaze, produced in a work of exploration in which the borders between development and evaluation of MRI's applications were blurred.

CONCLUSION: TAMING MRI INTO RADIOLOGY'S CLINICAL GAZE

In this chapter, my first main point has been that the evaluation and concomitant exploration of MRI assessed MRI within the frame of existing technologies and according to the methods of the radiological gaze, even though it acknowledged MRI's non-radiological gaze as a potential for the future. Other visions of what MRI could be used for and how it could be developed originated in other practices (or gazes) than radiology's; they were not excluded, but set on the margins of the official project of evaluation of MRI.

As a whole, I have argued that MRI was made into a radiological technology as the result of its users' practices. I have singled out three kinds of practice that helped to make MRI radiological, the first of which was MRI experts' implicit treatment of MRI as a radiological technology in the assessment of its clinical value. Second, MRI users aligned MRI on radiology's visuality and clinical time; third, they developed classical radiological techniques for MRI.

I have pointed out that one main argument put forward in favor of MRI was its high *contrast.* I have also shown that many of the radiological developments of the MRI gaze outlined in this chapter dealt with the production and enhancement of radiology's *contrast* through MRI.

What then was *contrast* in an NMR image? We might usually conceive of contrast as the difference between bright and dark in a black-and-white picture, for instance a photograph. As photographic technology is based on light beams travelling from objects through the camera's lens apparatus onto a film, the brightness or darkness of a part of the photographic picture would be mostly dependent on the brightness or darkness of the object being photographed. Contrast enhancement could then be obtained by image processing as an increase of the differences between the brightest and the darkest points: an extension or distortion of the scale of shades of gray in the picture so that bright objects or zones appear brighter and dark ones darker.

However, in MRI the image was not a result of the action of light; the beams at work were other kinds of electromagnetic radiations, provoked and constrained by the MRI device—which could be done in a range of specific, different ways through different pulse sequences. The MRI researchers whose work I have studied used, explored and developed pulse sequences and MR-imaging techniques that brought out bodily objects (often, bodily tissues) as bright on one kind of MRI scan and dark on another. What was visible on an MR image was defined by the visible differences between parts of the same image.[59] Some structures like tumor, surrounding edema and healthy tissue appeared as clearly separated on one scan commanded by one pulse sequence, or indistinguishable from each other on another commanded by another sequence.

In other words, *contrast* was an actively constructed feature of MR images; a feature that was the basis of the very visibility of bodily structures brought into medical being through MRI. The contrast to be obtained was thus a *specific* contrast, a visual-quantitative difference intentionally constructed through pulse sequences between the objects that the researchers wanted to find, oppose, hold apart.

Both the evaluative arguments about MRI—MRI being *better* at contrasting tissues and separating the normal from the pathological, and *unique* in its potential for tissue differentiation and characterization—and the development in practice of MRI's radiological gaze show that the contrast that researchers attempted to achieve through and with MRI was aligned with pathological anatomy's description of the body, i.e. with radiology's anatomo-clinical gaze.

Sociologist Kelly Joyce has recently argued that in the early 1980s the quantitative character of MRI (the representation of data, the use of color) was abandoned for a black-and-white, all-pictorial practice of MRI representations.[60] The present chapter demonstrates that Joyce's interpretation does not hold. First, the first section of this chapter has shown that well into the 1980s MRI researchers (many of them radiologists) highly valued the potential of MRI as a quantitative measurement method, alongside the acclaimed anatomical-pictorial powers of MRI. Second, by accounting for the *practices* of MRI technology I have shown that, for instance, the Uppsala MRI group's use and development of MRI retained an explicit *duality* throughout the 1980s, in which quantitative methods constituted areas of research in their own right. I have demonstrated that the MRI methods that this group (and other radiologists) used and developed were both visual and quantitative, where these two aspects informed and constrained each other. In other words, and as the following chapters will further demonstrate, the quantitative practices of modeling molecular interaction in MRI were actively pursued in the 1980s—certainly not abandoned.[61]

Joyce also argues that a "visual turn" in contemporary culture, together with radiologists' increased power since the 1970s (also the result of this visual turn) and a backlash in opinion against physics and nuclear research explain why MRI turned visual.[62] In my view, such broad contextual explanations are important as they inform our understanding of the history of MRI, but they are far from sufficient to *explain* it. The present chapter contributes with a study of practice which has shown how MRI "went radiological" in specific settings. I have demonstrated that MRI's going radiological had to do with the specific kinds of visuality (bifocal, anatomo-clinical, seeking specific contrasts) that the technology was made to perform, which were realized through the quantitative means of physical-chemical research, rather than with a visual turn *per se*.

Finally, an underlying theme of this chapter has been the instability, or uncertainty, of the body perceived through MRI. This instability was among others a consequence of the multiplicity of possible MRI bodies depending on the imaging methods used (pulse sequences). I understand the alignment of MRI on radiology's anatomo-clinical gaze as one disciplining of this instability, a taming of MRI within radiology's clinical gaze; and in the following chapters I shall explore other stabilizations of the MRI gaze.

The next chapter will follow a chronology parallel to that studied here, and investigate how MRI's radiological visuality operated in the clinical practice of another discipline—psychiatry: How was the open-endedness of MRI handled at the crossroads of psychiatry, individual brains and MRI's radiological-anatomical gaze?

interlude

science porn & stripping the body

Figure 9. MRI image of the "anatomy of [hetero]sexual intercourse".[1]

The coalescing of *vision* with *public display* in radiological culture is obvious in the light of the early cartoons published in the popular press at the beginning of the 20th century. Media scholars Solveig Jülich and Lisa Cartwright both show that X rays soon came to stand for powers of visual penetration—seeing inside wallets and beneath clothes, reading thoughts—and were a space for voyeurism, erotic fantasies, but also a threat to privacy and well-kept (e.g. political or sentimental) secrets. The voyeurist dimension of radiological display provided a cultural site for fascination (attraction and repulsion), fantasies, and a perverse gaze.[2]

Cartwright also emphasizes the threats to privacy posed by the radiological gaze. Commenting on an early critical editorial about X rays, she writes that "the X ray signifies the ultimate violation of the boundaries that define subjectivity and identity, exposing the private interior to the gaze of medicine and the public at large." [3]

In contemporary culture, the perverse roentgen gaze is probably best represented by science-fiction novels and movies (one example is Fredric Brown's ironic novel *Martians, go home*, in which a horde of irritating Martians with X-ray vision suddenly come to the Earth, their pleasuring pastime being the disclosing of people's most intimate private lives, and lead the world to political chaos).[4] Calling MRI "magnet roentgen" brings in the voyeurist dimension of display and the privacy of what is enclosed within the body—and disclosed by MRI's radiological eye.

YouTube user bstuder (also called Brian) implicitly questions the limits of MRI's peering into the human body in his episodic video diary posted on the Internet ("The Daily Shave").[5] Brian introduces the topic as porn in a tone that makes it sound unbelievable:

> *Welcome to the daily shave! […] Today we're going to talk about porn. Not just regular porn, but science porn.* [laughs] *This is crazy.*

Brian tells of a TV program he saw in which MRI research was presented that studied how "the female looks like inside before orgasm, after orgasm, and during orgasm." He attempts to explain how the study worked and gives a sense of the absurdity of the situation, as he views it:

> *So what they did was that they took one of these big, eh, MRI tubes, and they took out the table cause there wasn't enough room for a guy and a girl, right, so then they had the guy, eh…*

After confused explanations of what took place within the MRI scanner (they were "trying to do their thing"), Brian tells somehow unclear stories about how the sexual activity and the imaging had to be synchronized on each other, forcing the research subjects to stop intercourse so that MRI data could be registered. Brian explains that "the guy left", so that they could "take pictures" of the woman masturbating. Brian makes fun of the collision of genres between, on the one hand, the constraining experimental settings and the expert knowledge of the MRI research and, on the other hand, the erotic charge of what is actually taking place in the scanner:

> *I don't know why they did this, but they wanted to see, like, eh, the inside of a female, see the movement of stuff […] and let me tell you, I had no clue what I was looking at* [smiling] *yeah I did, but not on the inside […].*

Brian brings up the voyeurist dimension of this radiological gaze explicitly at the end of his narrative about MRI porn, when he points out that *looking* would be the most exciting part of participating in such a project:

> *The reason I'm bringing this up is, if there is anybody else out there that wants to go on an MRI with me, for science, bring it out, cause, I will. I'll do it for free* [shrugs]*. Or I'll just be looking. If I won't be looking I won't do it. You'd have to pay me then.*

The interesting thing about Brian's comments is that he seems uncomfortable: amused, fascinated, and at the same time trying to give a disinterested image of his relation to this high-tech "science porn". This corroborates Cartwright's argument about early radiology: that X ray "was [...] frequently regarded as socially transgressive." [6]

The research Brian refers to is most probably a project conducted at Groeningen University (The Netherlands) in the 1990s, whose purpose was both to test whether MRI was suited for studies of coital anatomy, and whether earlier assumptions about the shape and position of genitals during heterosexual intercourse could be confirmed or corrected. The project was summarized in a 1999 scientific publication in the *British Medical Journal* (BMJ) and had a defensive tone when explaining how the researchers came to start their project.[7] The authors' formulation of the acknowledgments also suggests that they encountered social difficulties in realizing the project. It also emphasizes the ethical concern of eventually putting intimate MRI scans on display: "We thank our volunteers for their cooperation, laughter, and permission to publish intimate MR images of them; those hospital officials on duty who had the intellectual courage to allow us to continue this search despite obtrusive and sniffing press hounds [...]".[8]

My interpretation here is that it was the act of display itself that was considered ethically sensitive—not that of possible identification of bodies. Consider for instance the image used as an introductory background to this interlude: it shows one of the published MRI scans of the Groeningen study, vertical cross-sections from the side. Whereas we may recognize two bodies engaged in a penetration act, the published MRI scan did not include any part of the body above the chest (and almost no legs); among others, no face or skull was part of the published frames. Obviously the threatening of intimacy was linked with strong feelings of exposure motivated by more than could be recognized (even by experts) on the MRI scans themselves.

Maybe in order to reinforce an aura of scientific credibility, the authors adopted an uncomfortable position in the BMJ article: first situating their MRI research on sexual intercourse in a grand historical continuity starting with Leonardo da Vinci's drawing "The Copulation" (1493), and later lowering their explicit motives to simple "artistic and scientific curiosity". Unsurprisingly (cf. earlier Interlude), the major part of their discussion was entitled "Anatomy revealed" and brought answers to the historical questions of the shape of the genital anatomy during sexual intercourse. The article's conclusions are summarized in a quite grandiose tone:

> What started as artistic and scientific curiosity has now been realized. We have shown that magnetic resonance images of the female sexual arousal response and the male and female genitals during coitus are feasible and beautiful; that the penis during intercourse in the "missionary position" has the shape of a boomerang and not of an S as drawn by Dickinson; and that [...] there was no evidence of an increase in the volume of the uterus during sexual arousal. [9]

However, neither the high-technological settings of the experiments, the timing of the intercourse on MRI acquisition times, nor the use of pharmaceuticals prevented the authors from explaining that what they found was quintessentially *nature*, as their intriguing last words illustrate:

> Magnetic resonance images, objective as they are, show the anatomy of human coitus and the female sexual response that is true to nature.[10]

The notion of nature as it is deployed by the authors of the Groeningen study may be better understood in the light of anthropologist Simon Cohn's critical comment on the notion of life deployed and reinforced in functional MR imaging (fMRI) of the brain. Cohn argues that life as studied with fMRI is a construct taken as a phenomenon *in itself*, which it is possible to isolate, produce and study in the brain in experimental settings. Cohn opposes this notion of "life itself" to life conceived of as the process "by which we live our lives" i.e. essentially entangled with social and human interactions. He writes:

> The 'life itself' that the imaging technology [fMRI] portrays is formulated as being the functional essence of an individual's brain, precisely because it conveys nothing of the living person beyond the restricted confines of the scanner and the experimental design. [...] Life becomes 'detached' – it is a capacity of the body, rather than of being human, that can be stared at from afar. [...] One could argue that, in so doing, human motivations, responsibilities and so forth are being neatly side-stepped. But what I am contending is that, in so doing, the person is actually being reconfigured, such that in some contexts at least the person does not have any life other than this life itself. [11]

What Cohn writes about the brain and life applies well to the notions of body and sexuality in the Groeningen study: sexuality as studied with MRI is a construct taken as a material "capacity of the [anatomical] body"—which it is possible to isolate, produce and study unchanged in individuals in experimental settings, as opposed to sexuality conceived of as a capacity "of being human" i.e. essentially entangled with social, human and complex bodily interactions.

A historical mystery resolved about the most intimate secret of mankind—the heterosexual anatomy of the missionary position? What the Groeningen study rather consecrated was that MRI, the radiological gaze's new instrument, gave the proof of its technocultural powers not only to disclose the intimate, but also to effectively strip it of its social, subjective and other embodied components in its construction of the natural anatomical body.

[4] seeing all our patients' brains

introducing MRI in clinical psychiatry

[T]he image is more than just a depiction of a body part from a certain perspective; it also bespeaks assumptions about mind-body relations as well as valid methods for obtaining medical knowledge. In other words, to accept the cerebral body [i.e. the idea that the most important organ in our bodies is the brain and that it defines who we are] is to accept both a particular account of the human condition and the assumptions and methods that produced it [...] .[1]

Robert Martensen, *The Brain Takes Shape* (2004)

The Brain Takes Shape, from which this chapter's introductory quotation is taken, is a history of the emergence of the *cerebral body*, i.e. the early modern philosophical, medical, and ontological shift towards a modern understanding of the brain as the most central organ of the body and the person. Historian of medicine Robert Martensen demonstrates how the solid parts of the brain became a potential, but disputed, repository of the spirit/mind, as part of changing cultural-scientific understandings of the body. Martensen shows that the early modern natural philosophers' shift towards taking the solid parts of the brain into consideration went hand in hand with the establishment of *likeness* (a notion that truth was contained in the image itself) as a dominant mode of "representing the real".[2]

Martensen emphasizes the importance of the works of Oxford physiologist Thomas Willis in the early 17th century, and his model of the mind linking together theories and depictions of the brain with theories of "human conduct." According to Martensen, "Willis made mind adhere to the brain as it never had before," and it is therefore in his work that the most crucial historical shift towards the establishment of the "cerebral body" can be found. Martensen concludes that "[i]n framing their accounts of the human condition in relation to their respective models of the brain and nerves, Descartes and Willis each formed a natural philosophy inextricably intertwined with their respective portrayals of the physical body itself." [3]

There is a huge historical leap between the early modern period and the twentieth century. However, Martensen's point is precisely that it is in the early modern period that the foundations of our contemporary understanding of the body and mind were laid, and that the cerebral body is a persistent assumption in our culture. Importantly, Martensen emphasizes the methods that make the cerebral body possible as crucial in "framing" accounts of the real into anatomy: "by demanding that medical knowledge relate structure to function in healthy and sick individuals," Martensen writes, "Western medicine's intellectual leaders from the Alexandrine anatomists, Galen, Vesalius, Harvey, Willis, and their intellectual kins on down to present-day masters of genomics have placed extreme emphasis on materialism as the only valid basis for knowledge." [4] Martensen therefore emphasizes the continued urge "to demonstrate [...] the cerebral model's existence as a taken-for-granted piece of cultural furniture in biomedicine."[5] Understanding what happened at the crossroads of the histories of brain sciences and MRI as a specific method of depiction is part of this endeavour.

"The quest for an image of the brain", to paraphrase the title of a book by psychiatrist and neurologist William Oldendorf, is about more than a radiological obsession with a specific organ. As works such as Robert Martensen's *The Brain Takes Shape*, Joseph Dumit's *Picturing Personhood*, and Anne Beaulieu's *The Space Inside the Skull* illustrate, medicine's shifting efforts to produce depictions of the brain have been inscribed within a historical project of conquering the brain as the residence of the mind.[6]

Psychiatrists' early interest in MRI is therefore not unexpected. The first Swedish attempts to integrate MRI in brain sciences and psychiatric clinical practice were made by psychiatrist Lennart Wetterberg together with psychiatrists Lars-Olof Wahlund, Jan Sääf and Ingrid Agartz, at the Karolinska Institute (St. Göran's Hospital) in Stockholm. Wetterberg and his early interest in what was then still called NMR imaging were introduced in Chapter 2. Whereas the previous chapter has focused on the integration of MRI into radiology, here I want to follow up what happened with the the technology in the setting of the psychiatric clinic at St. Göran's Hospital. This chapter addresses predominantly the clinical, diagnostic *use* of MRI, whereas Chapter 5 focuses on the clinically based MRI *research* at St. Göran's (as we shall see, the boundary between clinical use and research was often flexible). In the present chapter I use the specific example of the introduction of MRI at St. Göran's Hospital to study how the relationship between anatomy and psychiatry was constructed in practice.

This chapter thus aims to understand how the relation between MRI, MRI scans, brain anatomy and psychiatry was configured in the 1980s. I shall answer the following questions: How did Wetterberg and his colleagues introduce MRI in their psychiatric practice and what did they use and develop MRI for? What place did the brain take in psychiatric practice with the introduction of MRI at St. Göran's Hospital? Did MRI lead to a biologization of psychiatry or of concepts of the mind?

But before I engage with these questions, I will outline how Wetterberg got hold of an NMR scanner and thus situate his narrative as that of a "maverick scientist"—someone whose goals and methods were on the fringe of established science, and marginalized by established actors.[7]

WITHOUT THE AUTHORITIES

an (almost) unexpected support

In December 1981, the science journalist Kjell Lindqvist reported from the annual Swedish medical congress (*Läkaresällskapets Riksstämma*) in an edition of the daily popular scientific radio program, *Vetandets värld* (The World of Knowledge), which would turn out to have a decisive impact on MRI's future in Sweden. Lindqvist began the last part of the program by noting that financial restrictions were weighing heavily on psychiatry, and that "new strategies" were needed as psychiatry was also beginning to use costly medical imaging devices. The reporter then introduced the Stockholm professor of psychiatry Lennart Wetterberg as someone who decided to handle this problematic situation in a "somehow unSwedish manner". Taking his cue from the imaging technologies that had begun to enter psychiatry's world abroad, Wetterberg presented MRI as a

> *diagnostic method that is coming quickly, and one where there ought to be research from the outset. But this is about an instrument, or a device, that costs five to six million; we can't expect the state and county councils to invest now when they are cutting down on costs—and that is a major problem.*[8]

Whereas Wetterberg attempted to stress the importance of psychiatric research at large, Lindqvist repeatedly came back to the "magnet camera" in most of his questions. The reporter argued that Wetterberg "needed a special device to point at" when raising funds, and emphasized the necessity of popular fund-raising for the "NMR camera" by drawing a parallel with how, long before, appeals had been made to the Swedish people to contribute to the financing of an armored cruiser for the country.[9]

Lindqvist concluded the program by encouraging listeners to call St. Göran's Hospital for additional information, and by coining a metaphor to which journalist Birgitta Rennerstedt would refer a few months later: MRI was "psychiatry's armored cruiser" serving the country's common good:

> *If you are interested in helping Professor Lennart Wetterberg and his colleagues' raise funds for, what should I say, psychiatry's armored cruiser in the form of an NMR camera to look into the brain with—please call 13 05 00 in Stockholm to learn more about it.*[10]

According to Wetterberg, this radio program had a decisive effect on at least one crucial listener. Wetterberg recalls that someone who had heard the program came a few weeks later to St. Göran's, between Christmas and New Year. That person had heard that Wetterberg needed funds for an NMR scanner, was about to emigrate and "wanted to leave 20 000 for a camera. Which turned out to be 20 000 shares worth five [four] million SEK!" As Wetterberg's target was to gather 20 million SEK, the donation did not solve the whole financial aspect—but it was a solid enough argument to keep on working on the project.[11]

Wetterberg says that his early plan was to use a space outside the children's hospital at Sankt Göran's to install the NMR device. These devices were built with a "permanent magnet", which was too heavy to be placed on a standard floor. A soil survey was thus started, which soon led to the preliminary conclusion that the envisaged location was not suitable. A reason for this was the proximity of the underground station and lines next to the hospital: The passage of trains would create electromagnetic disturbances that could affect the content of NMR measurements and the legibility of the NMR images.[12]

Wetterberg says in our interview that at that time a retired consultant who had heard the radio program contacted him and said he was interested in conducting his own study of the electro-magnetic conditions and fuzzy currents around St. Göran's Hospital. He would in particular study the conditions around the site that was envisaged for the NMR scanner — and he would do it for free. He soon showed that the electromagnetic conditions would be favorable if the NMR room were shielded.[13]

Wetterberg sent in an unsuccessful application to the Research Planning and Coordination Council (*Forskningsrådsnämnden,* FRN) for NMR funds in 1983, and applied again in 1984 for an additional 7 million SEK to supplement the 4 million SEK private donation.[14] In April 1984, Wetterberg also officially asked the central administration of the health care district for a decision concerning the location of an NMR unit. Although a decision had been promised for mid-September 1984, a range of questions needed to be answered by different administrative instances during the summer of 1984. Among these was the question of how the county council and the Karolinska Institute (to which the research at Sankt Göran's Hospital formally belonged) were to share the costs of using an NMR unit.[15]

To inform his medical colleagues and gain their support, Wetterberg organized a couple of seminars at Sankt Göran's and *Läkaresällskapet* with a specialist in MRI in neurology from Pennsylvania, Larissa Bilaniuk, who reported how much more accurate NMR images were than CT, and how much hope there was that in the future it would be possible "not only to localize tumors, but also see what kind of tumor it is".[16]

But was it clear what these NMR images were? What were they expected to bring to psychiatry? In the next section I shall analyze parts of Bilaniuk's talk to understand what seemed to be at stake for psychiatry in NMR imaging.

early "magnet camera" horizons

Larissa Bilaniuk exposed the scientific principles behind NMR images, with all the possibilities and ambiguities that the technology's open-endedness created in terms of representation:

> [L. Bilaniuk shows a NMR image on her presentation screen, see Figure 10.] *Look here: This is black* [pointing at a large black structure in the

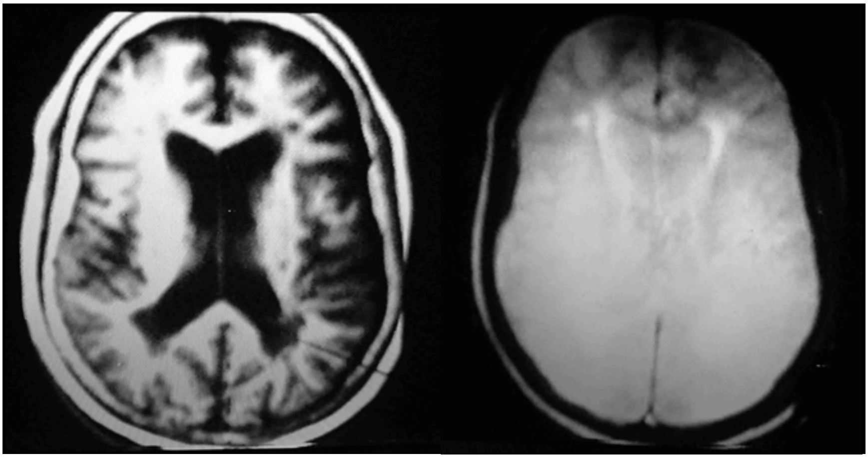


Figure 10. Two NMR images of the same brain. From Larissa Bilaniuk's talk.

> middle of the picture on the left], *and this* [pointing to the same structure on another NMR image, placed here on the right side] *this is the same patient; [and] this is white. Well, with NMR, when we are waiting for the signal we can wait a short time and we can wait a long time. Depending on how long we wait and how much we perturb this particular proton for example, it depends whether we get something black or whether we get something white. And we can use it to our advantage because here, one can appreciate even better the extent of white matter disease. So we have the option of perturbing the proton in various ways: we can send for example one wave and then send another one before it has recovered – and this is done on the basis of the knowledge of physics and mathematics – and the signal we get back will tell us information about this particular proton. And we can put it into mathematics or into an image. And this* [left NMR image] *is one way of looking at it, and this* [right NMR image] *is another. So we have these options in NMR.* [17]

What NMR could show in the brain was thus unstable, depending on the measurement technique that was chosen, and on the technology's parameters (i.e. commanded by the "pulse sequences" used to produce NMR data/images). Furthermore, the very nature of NMR imaging was ambiguous: NMR images were *both* images and physical-mathematical data.

Bilaniuk's presentation made clear that MRI made new spaces within the skull observable on a screen and visible to the psychiatrists for the first time:

> [Bilaniuk shows an X ray computed tomography (CT) image of a patient's brain.] *So one can look at this picture and say, yes there is*

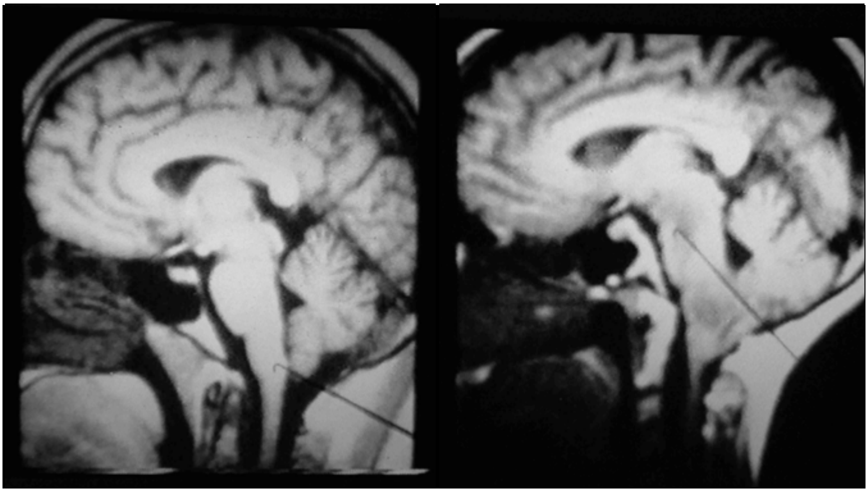


Figure 11. NMR images of a "normal brain" (left) and a brain with a tumor (right). From Larissa Bilaniuk's talk.

> *something wrong here, but how do you know how extensive it is? Is the abnormality only here, or is this the whole thing? It is very difficult to tell. And for a long time we have had to guess or estimate because you cannot see.* [18]

But *seeing* with the NMR gaze was nothing obvious, it had to be learned. Bilaniuk's pedagogical manner indicates clearly that Swedish psychiatry was a novice when it came to using brain scans showing anatomy to diagnose patients. Also, *seeing with NMR* meant first of all identifying the normal and the pathological, the pathological being the elements in an image which differed from the normal. In the same way that early radiologists used comparisons between different X ray scans to make sense of X ray images, it is only in learning to see differences that the NMR anatomic brain became intelligible, and that anatomy meant anything at all:[19]

> [Bilaniuk changes pictures and shows two new scans, shown in Figure 11]. *On a NMR scan on the same patient* [---] *I know that some of you are not used to looking at anatomy so I am showing you actually what is the basis of interpretation in picking up disease process. You have a template of normal* [NMR scan on the left] *and then you look at something that looks different* [NMR scan on the right] *and you try to determine whether it is abnormal. And if you look at this part of anatomy* [she points at a part of the NMR scan on the left] *which is the brain stem, you will notice that it's thinner here, has a belly here* [...], *and it's thinner here – and normally how it should be. However if you look up here* [points at a region of the NMR scan on the right] *that's not the case, and this is due to a tumor.* [20]

NMR imaging was unique in what it could show, but also in where it could look for it in the body – which had concrete implications for clinical treatment like surgery. Not least, Bilaniuk brought up at the end of her exposé how NMR images had huge implications for the patients' own relationship to their disease:

> *…and when this man who is a lawyer saw this [NMR] picture [of his own brain]—and here* […] *you can see that his visual system is riding up on top of his tumor— and eventually is going to be affected by it. No time before we have been able to visualize, during life, this type of relationship and this type of a picture. In this man's life, he made the decision* […] *to have therapy for this tumor* […] *but now he knows that there is a risk* […].

The horizons that NMR imaging opened within psychiatry thus seemed manifold, urgent, and marked by ambiguities. First of all NMR imaging was to open a visual world, where it was possible to see within the now transparent skull instead of guessing from signs on the outside of it. But seeing presupposed showing: showing the diseased and the normal, showing to the doctor and to the patient. The open-endedness of the possible showings was perhaps the most appealing feature of the new medium; not only appealing, this open-endedness had soon to be open for exploration.

getting hold of an NMR scanner

Fearing that an administrative decision about whether a NMR device should be installed in his department would take a long time, Wetterberg decided to act independently of the ongoing process. At a conference, he says, he had heard about a Finnish research group at the Technical University of Turku who conducted research into magnets at very low temperatures, and decided to pay them a visit. The ultra-low temperatures made it possible to reduce electrical resistance in the conductors and thus, to use much smaller magnets. This group had formed a company called Instrumentarium, and built a prototype of a low-field magnetic resonance imager called Acutscan. Wetterberg recalls that this prototype had cost about five million SEK but was to be sent free to a hospital near New York, where it would work as a kind of advertisement for Instrumentarium on the American market.[21] Wetterberg offered to pay cash and the parties agreed on a final price of 2 350 000 SEK — including installation. Instrumentarium's NMR device was dedicated to "research purposes";[22] it was their very first tomograph and was therefore not tested for clinical purposes.[23]

The issue of where to install the NMR device had yet to be solved. Wetterberg says that he had temporarily given up the regular administrative process, and the rumor spread that he needed a space for the NMR scanner. "A grateful patient", as he puts it, had a villa in Bromma and offered to let the camera be installed there. The proximity of the psychiatric institution at Beckomberga made the whole idea reasonable. But when it became known to the county council administration that he might have plans to install the NMR device in a private home in Bromma, it urged Wetterberg to reconsider this decision and to consider installing the scanner at Sankt Göran's instead.[24]

The end of the summer and fall of 1984 saw an acceleration of the process. "The local administration", Wetterberg says in our interview, "—those who had control over this area, directly over the hospital—, the union and colleagues, and even the radiologists here at Sankt Göran, everybody was positive to the whole project."[25] A small room that had been used as a storage room became the next candidate space for the NMR device. The board of the institution agreed to the installation of the NMR unit on August 23rd, 1984.[26] A few days later, the managers of the health care district Stockholm West (responsible for Sankt Göran's Hospital) expressed their support:

> The health district management will support attempts to adapt the space in question for a small MR camera. It is of great importance for doctors and other personnel within the health care district to be given the possibility to develop their knowledge of a modern radiological technology that will also be introduced and developed within SLL [the Stockholm County Council].[27]

In the local hierarchy, two actors who according to Wetterberg were not greatly in favor of the NMR project were the health care county council politician Leni Björklund and the director of the health care administration Bo Ringholm. Wetterberg relates this to the general fear of uncontrolled high costs caused by MRI all over Europe in the early 1980s. His second interpretation is that politicians did not want to allow processes they had formal responsibility for but no control of. "And that was pretty normal", he says, "Here comes someone with his own funds who wants to do something they don't have control upon, something they can't prevent. And when they tried to prevent it I still installed it [the NMR device]." [28]

The directors of the health care district Stockholm West also delegated to the technical department the task of planning the building work necessary for the installation and functioning of the NMR scanner, as well as proposing a preliminary budget and time plan. "The goal", they wrote, "should be for the space to be ready for utilization during the fall of 1984."[29] The work necessary in order to adapt the building to the NMR scanner, including radio-frequency shielding of the room, was completed quickly. Like that at Uppsala, St. Göran's Hospital's project of installation of the NMR device and adaptation of hospital space to it became a project of its own, as a 1985 publication shows.[30] Wetterberg invited the press and on 21 December 1984 he took his first NMR images. From his first investigation of the low-field scanner to St. Göran's first NMR picture there had been "less than three months."[31] The daily paper *Dagens Nyheter* reported the event and presented the new technology as Stockholm's first MRI scanner, and the second device in Sweden just after Uppsala's installation. The St. Göran's scanner was also the first MRI device in the world to be placed in a psychiatric clinic, according to Wetterberg. [32] The device was defined as a research tool—"to investigate what happens in the brain with different diseases".[33]

INTRODUCING IMAGING AND BRAINS

clinical introduction

Wetterberg asked psychiatrist Lars-Olof Wahlund to establish the grounds for clinical MRI-work at St. Göran's Hospital, together with research engineer Jan Sääf. Both Sääf and Wahlund, who was the "chief clinician" for the NMR camera, had completed their Ph.D. theses at St. Göran's Hospital earlier in the 1980s. M.D. Ingrid Agartz begun her Ph.D. studies in psychiatry at St. Göran's at about the same time as the scanner was installed, and was focusing on NMR research in her doctoral work.[34]

"First on the program," Wetterberg's words read in the *Dagens Nyheter* article about the inauguration of NMR, "is a screening of about 2000 chronically diseased patients in the region of Stockholm, with problems that have been localized to the brain. Every examination takes half an hour. We can manage eight examinations per day." [35] Imaging of patients and healthy volunteers started directly after the installation of the NMR scanner.[36]

Wahlund explains that he and Sääf started with virtually no knowledge of the technology and explored the production of NMR images by themselves, in close cooperation with Instrumentarium. Soon they developed an infrastructure for their clinical work and reinforced their team with a secretary and a research nurse. The patients examined with MRI were mostly referred from the psychiatric clinic at St. Göran's Hospital, especially from the psychiatric emergency ward. Wahlund adds that he established a cooperation between his group, the departments of

Figure 12. Staff guiding a patient into the MRI scanner at St. Göran's. The white helmet-like shape pointing towards the reader is a head coil.[37]

radiology and pediatric radiology at St. Göran's Hospital, and the department of neuroradiology at the Södersjukhuset Hospital in Stockholm. The two St. Göran's departments sent patients to Wahlund and Wetterberg's group for MRI examinations of other organs than the brain—and their staff participated in conducting MRI examinations. Neurologist Olle Marions from Södersjukhuset regularly assisted the St. Göran's MRI group in their diagnostic interpretation of the MRI scans.[38]

In our interview, Wetterberg explained that for him the most important thing about MRI was to image and examine the patient's brains, "to be able to demonstrate specific lesions in the brain, that were of a more subtle nature than what you could see with an X-ray examination", and to follow up signs of pathology over time.[39] Agartz, Wahlund, Sääf and Wetterberg wrote explicitly in 1987: "As our focus of interest is the pathology of brain tissue, the majority of the cases presented are brain studies." [40]

Patient after patient coming to St. Göran's with symptoms identified as psychosis, manic-depressive symptoms, dementia, anxiety, or addiction was taken through the NMR scanner and the clinical tests. Agartz explains that the NMR group "examined patients for research purposes" but "also documented any sign of organic brain pathology on the images" and assessed the patients' brain status.[41] Lennart Wetterberg elaborates on the reasons behind the brain-imaging procedure and its effects in our interview:

> *We had five care units [at St. Göran's Hospital] for 75 patients. Patients came in with unclear symptoms and we could examine them in the magnet camera. The examination took twenty minutes and the personnel could come down and see the pictures directly. They became interested in the changes in the brain.*
>
> *And there happened two things. [First,] it mattered that people saw that we could explain the symptoms in a number of patients. It could be a tumor in one of the frontal lobes—they can grow and get really large before they give psychiatric symptoms. And we had a number of such patients that had been going for a long time without any clear diagnosis. I especially remember one who had been in family therapy for two years; that meant suffering for the patient and a burden for his family—and nobody could find an explanation. But he had a large tumor growing slowly here…* [Wetterberg points to his head].
>
> *The second thing is that there was a weakness in psychotherapeutic work—that the appearance of the brain could not be taken into consideration. Sigmund Freud had said that the brain "was a black box, I don't know what takes place there", but suddenly we could see changes in the brain with the magnet camera.*[42]

The researchers were thus exploring to what extent NMR images produced in different ways could confirm or explain patients' symptoms, by bringing out an "organic" cause, i.e. a change in the shape or state of the brain matter that would explain neurological or behavioral changes. Wetterberg's words that "suddenly we could see changes in the brain" (or, as he formulates it after reviewing the transcript of our interview: "suddenly we could see all our patients' brains") indicates that imaging was not only a practical method; rather, he suggests that NMR enabled a "brain turn" in the kind of psychiatry that was practiced at St. Göran's Hospital.[43]

Wetterberg's group reported encouraging results after half a year, and suggested that their low-field NMR could be a competitive diagnostic tool for clinical use due to "such spatial resolution and high sensitivity to pathological conditions"—not least when compared to the expensive high-field devices such as Uppsala's, "which dominate the market today." Still, establishing the specific value of high-field versus low-field NMR scanners, they argued, could be done only by "extensive clinical comparisons", i.e. broader clinical studies.[44] This was in itself an effective way to explain why their continued exploration of NMR's clinical value for a large population of psychiatric patients was needed, and to promote the clinical use of MRI.

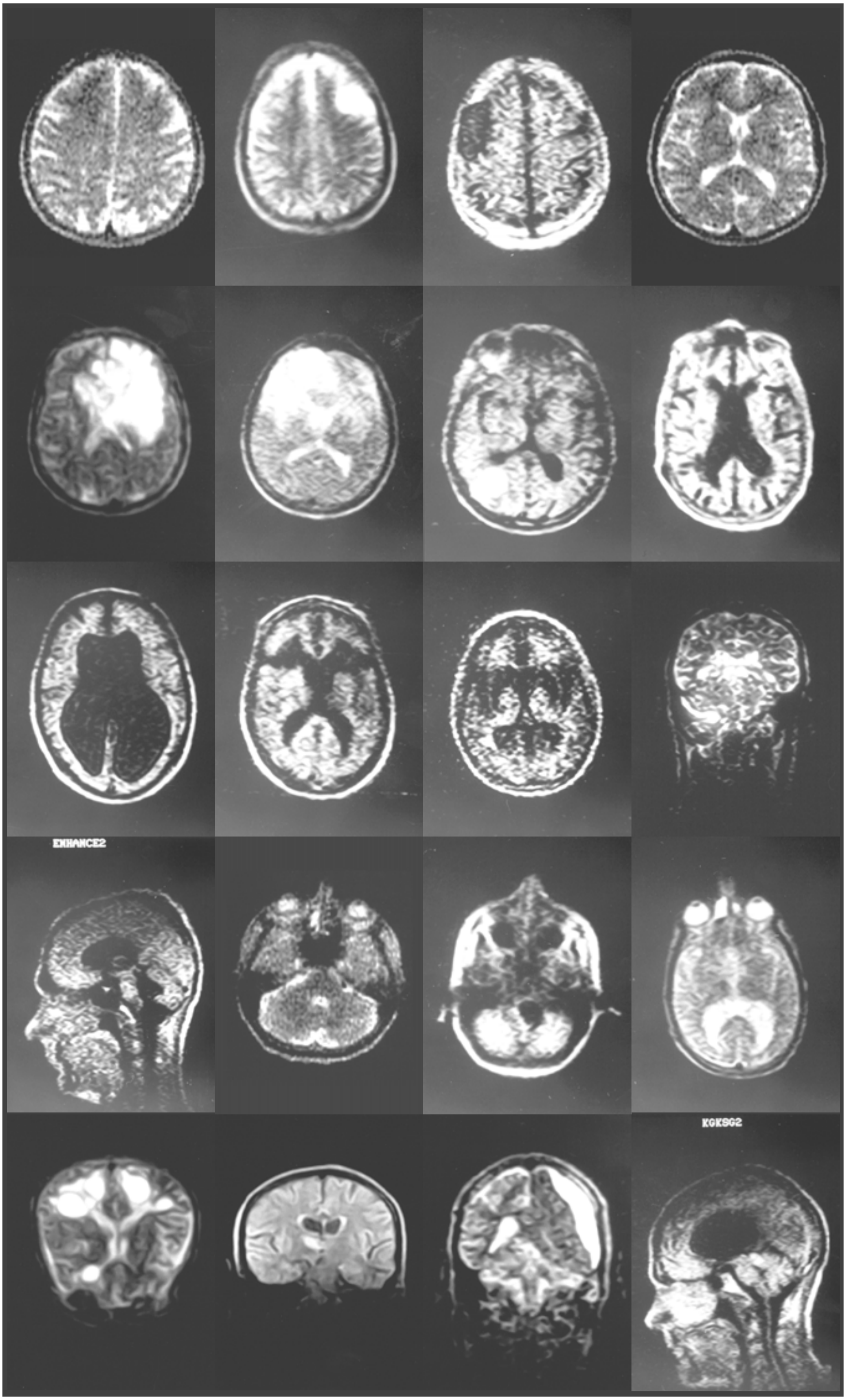


Figure 13. A gallery of brain portraits. Montage from a selection of photos of MRI scans performed at St. Göran's in the 1980s.[45]

screening the psychiatric population

In the first one and a half years, about 1000 patients were examined with St. Göran's MRI scanner, including some given whole-body examinations.[46] Patient after patient, brain after brain, a gallery of NMR brain portraits emerged as the reflection of the psychiatric population.

Wetterberg's group conducted a systematic MRI screening of the psychiatric population referred to St. Göran's in the second half of the 1980s (1986-1990) as part of a clinical study. Most patients were in an acute state when referred to St. Göran's, and they were usually scanned less than three months after their first visit to a psychiatrist. The "Case 3" report quoted below from a research publication was one in many (probably about 1500) patient histories encountered by the researchers Agartz, Wahlund, Sääf and Wetterberg during this broad clinical study:

> Case 3.
>
> A 75 years old female, previously in good mental health, attended our emergency-unit accompanied by her husband because she had become increasingly depressed and had undergone personality changes over the previous three months. On examination the patient showed inhibited motor response and lowered mood but no psychotic signs. Her somatic status, including neurological examination, was normal and she went home after being prescribed antidepressant medication. The couple returned one week later since the patient had become increasingly listless. On reexamination she was found to have normal neurological status apart from a right-sided tremor in the leg and arm.
>
> A MRI examination was performed immediately and a large expansive process with the appearance of malignant glioma was observed in the frontal lobes the patient was transferred without delay to the department of neurosurgery for continued investigation and treatment.[47]

Thus MRI filled an immediate clinical function, leading for instance to the transfer of patients to surgery when appropriate. The main clinical purpose of the screening was to identify the patients with organic brain disorders, i.e. psychiatric patients whose symptoms were caused by local physical lesions in the brain such as a tumor, hemorrhagia (bleeding), cysts or infarction.[48]

Reports of clinical cases were published that I read as (heroic) narratives of MRI's role in Wahlund and colleagues' diagnosis of psychiatric patients. In some cases, MRI worked as what I call a *fixative*, bringing a "period" to a diagnostic question, by definitely confirming a tentative diagnosis that had been established with other radiological (anatomical) technologies like X ray computed tomography (CT). Sometimes MRI "saw" pathological changes in the brain structure that other technologies did not view, and acted rather as a *cutter* – an oblique one. What made this happen was that MRI could image plans at any angle in space, thus "cutting through" the usual vertical or horizontal slices that other imaging technologies could offer.[49] On MRI images lesions appeared that had been lost between the slices of CT: MRI cut through radiology's existing spatial diagnostic frames. But most often in the reported cases, MRI worked as a *filler of diagnostic gaps*. In one such narrative, the patient, "a 34-year-old man with a rapidly progressing change in personality characteristics" had been examined with X ray computed tomography (CT) showing a probably limited tumor which could not explain the man's changing personality. Those results were surprising (the report mentions "the discrepancy between the severity of the symptoms and the relatively moderate CT findings") and an MRI examination was conducted, which "repaired" this discrepancy: "a massive tumor infiltration could be demonstrated." MRI thus solved unexplainable cases by bringing out a morphological reason for changes that were not in agreement with other diagnostic signs or results, and filled the gaps between unsatisfactory diagnostic methods and patient behavior.[50] These narratives of what MRI technology afforded show that St. Göran's MRI psychiatrists articulated through MRI a relation between existing diagnostic methods, earlier unsatisfactory diagnoses, and the patients' brains.

In addition to the immediate diagnostic use of MRI, the St. Göran's MRI group aimed to produce statistics of the psychiatric population: How many were actually referred for different kinds of therapy that could not cure them, as what they needed was brain surgery? [51]

The large-scale analysis was conducted retrospectively. The patients taken into consideration were those without obvious neurological signs—i.e. clinical symptoms of damaged neurological systems, such as motricity impairment, that could already identify the disease. In order to explore correlations between clinical signs and NMR-based diagnosis, the patients were categorized into different groups: Patients with alcohol/drug addiction, anxiety, mania/depression, confusion/dementia, and psychosis, respectively.

The study concluded that 17% of the psychiatric patients examined at St. Göran's showed a "cerebral pathology", i.e. an organic disorder of the brain. This result, higher than could be expected from previous research on the subject, "underline[d] the importance of brain imaging to be part of routine diagnostic investigations in psychiatric practice".[52] It is amongst the patients with anxiety, confusion/dementia or depression that organic brain pathologies were found to the largest extent (in about 25% of these patients.)

The urgency of many situations patients searched help for at St. Göran's was emphasized by the possible severity of the consequences not only for the individual but also for society, as the researchers' case comments insisted:

> It is not unusual for frontal lobe tumors to be present with only depressive symptoms or pseudodementia. [...] Another dramatic example of tumors being manifested through psychiatric symptoms is as follows: a young man in the USA shot his mother and wife and then took shelter in a tower on the roof of a school building. From there he shot 14 children dead before he himself died from a police bullet in the head. The man had consulted a psychiatrist a few months before the tragic event, complaining that he felt strange. Among other things he occasionally became aggressive without reason and felt a strong need to take shelter in the tower of the school building and fire indiscriminately around himself. On post-mortem examination a malignant tumor was found in one of the temporal lobes.[53]

In my view, emphasizing the seriousness of even diffuse psychiatric conditions was a necessary argument in order to promote the use of MRI within Swedish psychiatry. The clinical study conducted at St. Göran's with MRI was in itself an argument for using MRI (and CT) in routine examinations of psychiatric patients with diffuse symptoms. Wetterberg, Wahlund and Agartz have argued both in publications and in interviews that, as previously with CT, psychiatrists did not routinely refer their patients for MRI examinations, although these were available in the 1980s. The usual reason for that was the priority system set around the available MRI and CT devices: a priority grade was attributed to each patient referred to a given MRI or CT unit according to the urgency and the expected diagnostic value of an examination; patients with lower priority grades would have to wait for a long time before being examined. As organic diseases, including neurological diseases, were often given higher priority than diffuse psychiatric disorders, "many psychiatrists d[id] not refer their patients for CT or MRI". [54]

The clinical study therefore recommended on the basis of its results that "it is desirable to have access to imaging neurodiagnostic resources for psychiatric patients to a greater extent than is usually present today", emphasized by the argument that "[t]he gains in relation to cost of nursing care are evident, and the MRI method should therefore also be made available for patients outside the university hospitals". But the arguments for a broader availability and use of MRI were not only economic, they were also ethical: "The knowledge which MRI provides helps both the treating doctor and the clinical researcher to understand the patient's symptoms and psychiatry is better equipped to carefully treat the mentally ill."[55]

At the same time, the "clinical material" gathered through systematic examinations opened up for NMR-based research on subjects that had been an important part of St. Göran's psychiatric practice, such as alcoholism and abstinence, dementia and schizophrenia. Whereas the boundary between clinical use and clinical research was an efficient way to acquire funding for MRI and to gain the technology a certain scientific value, MRI was in practice used both for psychiatric diagnosis (which I have more generally called clinical use) and for clinically based MRI research on the brain.[56]

Central directions of this MRI research are analyzed in Chapter 5; in the next section, I want to understand the role of NMR images of the brain in what begun as an unexpected, but soon mediatized, phenomenon: HIV-related dementia.

DIFFERENCE THROUGH DISEASE: PICTURES OF HIV/AIDS

During the spring of 1982, cautious reports of worrying observations from the USA were published in Sweden. Since the summer of 1981, an inexplicable number of young gay men had been reported to be seeking treatment in the USA for a rare form of pneumonia as well as Kaposi's sarcoma (a rare skin cancer). Soon (in May 1982), the mysterious set of symptoms was labeled "acquired immunodeficiency syndrome" (AIDS). In December 1982, the first Swedish AIDS patients were diagnosed at Roslagstull Hospital and Danderyd Hospital in Stockholm; and in February 1983, they were reported in *Läkartidningen*.[57] During the summer of 1984, Swedish doctors and health care officers published their concern that "[e]pidemiologic data and laboratory results suggest that an AIDS-infectious agent may already have spread in the homosexual population".[58] The same month a message was published in *Läkartidningen* confirming that the AIDS-related virus had been identified in Swedish men.[59]

An increasing number of articles on HIV and the progress of research were published in *Läkartidningen.* A war had started against a disease that was about to re-cast cultural notions of disease in Western societies.[60]

searching in the dark

During the lethal years of the early AIDS epidemic, the hypothetical cause of the disease was controversial. The mechanisms of what was in 1983 and 1984 identified by the Pasteur Institute (France) and Robert Gallo (USA) as a probable agent of the disease, an unusual kind of virus designated LAV and HTLV-III respectively, and later renamed HIV, were still at that time largely unknown. By 1985 a first consensus was reached in the scientific community: HIV was generally considered to cause AIDS.[61]

A few studies conducted in 1983-1985 identified diffuse forms of dementia as a not unusual correlate of AIDS. In 1986-1987 the fact that HIV had effects on the brain became ever more clearly established and results from larger studies were becoming public. Thus by the mid-eighties it became clear that many AIDS patients were afflicted by psychiatric conditions in addition to the somatic ones: among other symptoms, dementia, psychosis, depression and personality changes were reported. Yet how and why these symptoms appeared was unknown.[62]

Lennart Wetterberg recalls how he became a part of medicine's fight against AIDS:

> *[In 1986,] we admitted two patients who had developed symptoms similar to schizophrenia, but we did not recognize the type of lesion we saw in their brains on MRI. They were mainly located in the frontal lobes. There was a possibility that we had found a new type of lesion [characteristic of] schizophrenia. We therefore examined several patients with confirmed schizophrenia, but these patients didn't show such signs. It turned out that we were among the first in the world to demonstrate brain lesions in AIDS and HIV infection, a new diagnosis that had been described in 1984-1985. Those were the two first cases of HIV who started with psychiatric symptoms.* [Wetterberg shows a newspaper article] *[The daily paper]* Expressen *drew attention to it in a large article, [writing] that the magnet camera could perhaps help solve a part of the AIDS question.*[63]

In Stockholm, Roslagstull Hospital became the health care center for AIDS patients. Lennart Wetterberg explains that cooperation was soon established between St. Göran's psychiatric department and Roslagstull Hospital in the cases of dementia in AIDS patients. Wetterberg says that his group was among the first in the world to use MRI to demonstrate HIV infections in the brain and attempt to characterize these.[64] He got involved in research into possible changes in brain matter associated with AIDS: First, by importing what then was thought of as a promising substance against AIDS-induced dementia, "peptide T", and testing it on human patients in cooperation with Roslagstull Hospital; and second, by creating specific MRI images of the brains of demented AIDS patients.[65] Here I focus on the latter: how these images were created and promoted in the media, and with which notions of disease and difference. How the work of Wetterberg's group participated in the intensifying medical battle against HIV is unclear to me—but I want to understand what these images of HIV-infected brains seemed to *do* with understandings of the disease.

Not knowing what kind of organic changes to look for—but having the ability to look—Wetterberg's team examined the patients' brains with MRI.[66] The language of the publications in *Läkartidningen* was more assertive.[67] The patients whose brains were scanned and processed to identify the extent of the "damaged" area of the brain were submitted in parallel to a battery of twenty neuropsychological tests. Those tests aimed to assess their verbal fluency, memory, reasoning, tactual performance, etc. – these were established measures of psychological performance, and of known relation to the state and function of different zones of the brain.[68] The results of the study were alarming:

> We could see subcortical, predominantly frontal pathological changes in 75 percent of 40 HIV-1-infected homosexual or bisexual men on examination with a low-field magnet camera linked to an image-processing-computer-analyzer. No changes could be seen in a control group of 15 HIV-1-negative homosexual or bisexual men.
>
> The degree of [pathological] change followed the patients' stage of infection [...], the duration of the infections and neuropsychiatric symptoms such as impaired short-term memory. The psychometric tests showed an impaired function in memory, concentration ability and fine motoric capacity in all [HIV/AIDS] patient groups as compared to the control subjects.[69]

Whereas Wetterberg's group would later qualify these statistics, their initial claim was that a large majority of the HIV-infected patients exhibited brain damage, the effects of which were quantified with the neuropsychological tests.

displaying disease

Concretely speaking, Wetterberg's group purchased a computer device for image analysis to process MRI brain images and create a map of each patient's brain in which the zones with "pathological changes" were shown in different colors from the remaining part of the brain. The pathological changes were defined as zones with shorter NMR characteristics T1 and T2 than the normal—e.g. results obtained in controls ("apparently healthy

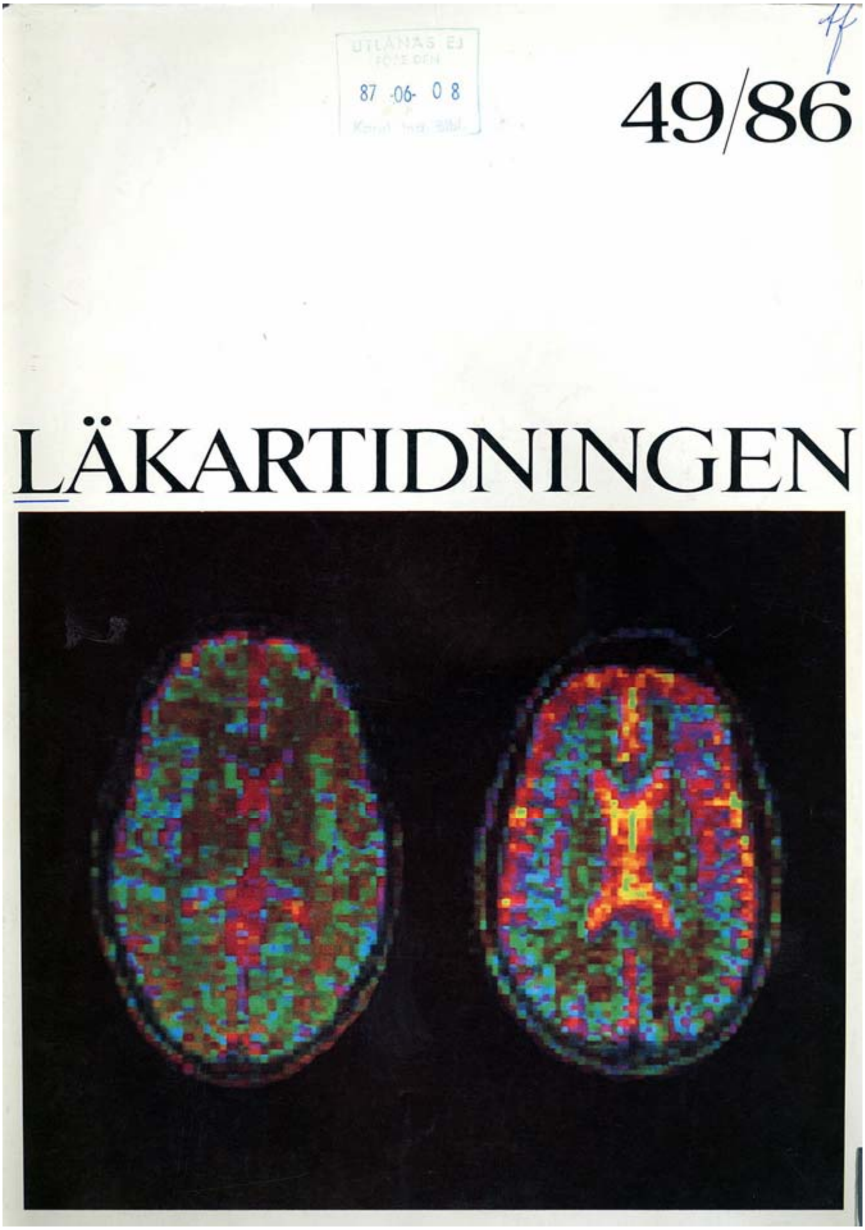


Figure 14. Front page of an issue of *Läkartidningen* in 1986. A caption inside the journal explains: "transversal depictions of the brain in a healthy control (left) and a patient with AIDS (right)".[70]

persons").[71] Figure 14 reproduces the color picture of two such brain scans—a normal brain beside an HIV-infected brain—published as the front page of *Läkartidningen* in 1986. *Läkartidningen*'s front page worked as a puzzle, the answer to which was given in a caption in the table of contents of the journal. The textless front page, implicitly to be read as left: normal, right: diseased, reveals a self-evident frame of interpretation which was based on a notion of difference, and created difference. [72] About such implicit codes, Joseph Dumit writes:

> [Anne] Barry's insight was that even if perceiving an image is primary to, or does not even need, its caption, it nonetheless is always a contextual, narrated practice, drawing on and drawing together other concepts [---] Brain images are powerful, memorable condensers of cultural content and concepts of human nature in this manner. Two adjacent images that look different ask to be seen as the essential characteristics of the labels that describe them.[73]

Using Dumit's words then, the two adjacent MRI pictures on the front page ask to be "seen as the essential characteristics" of the brain of an HIV-infected person and of a "normal" brain; thus the two pictures become a picture of dementia and HIV with all its connotations, and normalcy construed as the absence of HIV infection.

In *Läkartidningen*'s front-page image, the range of warm colors used to represent (in unclarified ways) the disease and its traces, too messy for the size and resolution of the front-page picture, seems to have conveyed a feeling of chaos, a worrying and destructive one. The picture of the rampant red and yellow dots in what I want to call the "HIV-brain" suggest too well the spreading infection, discovered by MRI and not only the doctor's eye—but also the public eye. Similar images from St. Göran's were published in 1986-87 in Swedish media such as the medical paper *Svar*, the daily paper *Expressen*, and the Danish paper *Det Fri Aktuelt*.[74]

The sensationalist character of MRI images of HIV-infected individuals' brains was obvious in *Expressen*'s 1987 article entitled "THE PICTURE OF AIDS" (*"BILDEN AV AIDS"*): The title and picture of two brains next to each other (one from a "healthy brain" and one from an "AIDS-infected" brain, the caption reads) covered about 75% of the paper space, effectively displacing the text to the margins. The short text constructed a heroic narrative in which Wetterberg was continuously called on the phone by relatives or American doctors wanting to send their son or patient to him, and his "elite team of researchers" worked intensely over the summer because "AIDS does not take vacations." Technology itself (and further funding) was offered as the possible key, as the reporter wrote: "The solution to the AIDS mystery may be close, thanks to a Finnish magnet camera and a Swedish image processing computer."[75]

MRI images thus put the brains of HIV-infected persons on display, and took part in the construction of a notion of the HIV brain through mutual difference.[76] Dumit argues that when traveling in popular contexts, brain images acquire a power of "catching up" readers in their frame, which he attributes to their iconic character:

> The key point for brain imaging is that as the image becomes more simple and iconic, it also becomes more subjective (personally invested in) and universal (generalizable to human nature). I suggest that these neuroscientific facts compel such reworking because they provide authoritative starting points along with combinatory possibilities.[77]

With which consequences? I want here to present and analyze more closely a TV program entitled "Knowledge of AIDS research" that was broadcasted in 1988 on public television, a major part of it being dedicated to St. Göran's Hospital's work on AIDS-related brain lesions. The program also re-situated technological work and images in their social and political context and contested their social consequences.

The TV-program section under scrutiny here begins with images of a person being moved into St. Göran's MRI scanner. The reporter asks a HIV-infected volunteer about his feelings at having his brain scanned. "Anders" is duly anonymized: the TV images of him are thoroughly blurred and his voice has been processed and distorted so as to render identification impossible—an expression of the social stigma with which HIV/AIDS was endowed. Anders' attitude to the brain scans was less dramatic than the reporter seems to have expected, because his frame of reference was death:

> *Reporter: This is the magnet camera that registers HIV patients' brain damage. [...] Anders has been examined a dozen times. What do you think about when you're lying there?*
>
> *Anders: Well, it depends what emotional stage you're in before you go into the tube...*
>
> *Reporter: Is there anything in these results that you would be afraid to know?*
>
> *Anders: No. [---] The worst thing [...] [when you have AIDS] is a death sentence. [...] So what can be worse than that? Answer: nothing. No, there is nothing I don't want to know.*[78]

The reporter's questions show that MR images of brains were expected to affect the patients examined—disclosing disturbing hidden truths about their disease status, but also about their mental capacities and personality. In contrast, Anders' answers re-situated these examinations and pictures as merely one in a broader range of tests and results to which HIV patients had to submit.

Figure 15. MRI brain of a healthy person.

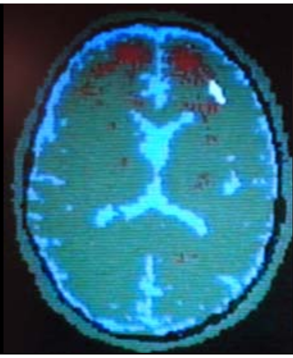


Figure 16. MRI brain of an HIV patient before AIDS stage.

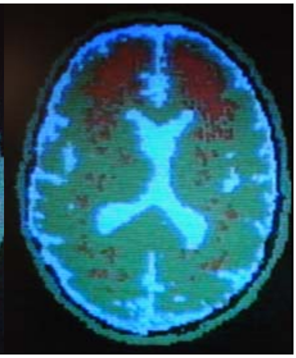


Figure 17. MRI brain of an HIV patient in AIDS stage.[79]

After this background of a dramatic tension between the patient and medical science's technologies of exposure, the reporter's interviews with doctors dressed in white coats in laboratory-like rooms seem strangely factual. She asks Jan Sääf, who works with the MRI images of HIV-infected brains, how they are produced and interpreted. What was the St. Göran's experts' discourse on what the images did? I reproduce below a quite lengthy dialogue in which the MRI images of HIV brains are described and explained; the images are reproduced accordingly (Figure 15-17).

> *Jan Sääf: If you look very closely, such a picture actually consists of lots of small picture points, small squares, and each such little point is actually a tissue sample from that place in the brain. If we have 100 000 little points or small tissue samples in a picture and take ten pictures then we're up to a million values. Our human brain cannot analyze this and we need instead to have a special computer that is especially designed for that, an image analyzer, that can cope with this amount of information.*
>
> [The image zeroes in on a MRI brain scan in green and blue colors, reproduced here as Figure 15.]
>
> *Sääf: In this case we have had the computer paint the healthy parts of the brain green. The blue areas are fluid in the brain. […] We can now look at a patient just before going into the AIDS stage. [A new MRI brain image is shown which has red areas in addition to green and blue, reproduced here as Figure 16.] What is most remarkable is that there are areas […] in the anterior part of the frontal lobes in the brain which the computer no longer recognizes as normal values.*
>
> *Reporter: Has anything happened?*
>
> *Sääf: Something has happened there, the metabolism has changed in some way, so that [the areas] get painted in another color, in this case red.*
>
> *Reporter: How does this patient feel when it comes to brain damage?*

> *Sääf: In this case there are no obvious neurological symptoms, clinically speaking. [---]*
>
> [The video focuses a third image now, with much larger red areas, reproduced here as Figure 17.]
>
> *Reporter: Eight months later…*
>
> *Sääf: Now the patient has entered the AIDS stage. And here we see that these red areas have grown very much. And we also see that there are islands of changes at the back of the brain, close to the neck still in the white matter in the brain.*
>
> *Reporter: What do you notice on the patient now then?*
>
> *Sääf: Now the patient can sometimes,… often shows neurological symptoms at that stage.*[80]

Sääf thus explained that MRI worked like a laboratory, performing a number of microscopic analyses, and that the computer acted as a data visualization device, interpreting the results of these analyses of brain tissue.[81] Hence, in Sääf's description, the images bring out a disease in a high-technological automatic way, and are therefore bearers of objectivity. Human intervention is not ignored, as s/he who handles the MRI-computer complex gives orders about how the computer should "paint" different sets of MRI values. However, this way to stage human intervention as limited to the display procedure reinforces the notion that MRI's analyses of brain tissues provided accurate descriptions of the biological reality in the brain. Furthermore, the way Sääf links the images of one patient to a scientific periodization of HIV/AIDS in different disease stages makes the MRI scans representative of *one* disease (HIV/AIDS) across individuals.[82]

The scientific character of the medium (MRI images and computerized image processing), and of the explanations of what it did (one million microscopic laboratory analyses in a series of pictures) contrasts strongly with how little knowledge is demonstrated of what it is that these images showed. Sääf, like his colleagues in other publications, referred vaguely to changes in metabolism "in some way" when explaining why abnormal MRI values appear that "the computer does no longer recognize as normal values." The reporter enquired about the relationship between these images and the patient's observable behavior, but did not get satisfactory answers, which reinforces a feeling of uncertainty as to what these MRI scans actually showed—and which consequences they had. Whereas Sääf adopted an expert-descriptive position, the reporter recurrently came back to the patient's phenomenological experience of his disease, making visible the gap between what sociologists have coined as disease (the scientific notion of a given pathology), which is what MRI handled, and illness (the lived experience of it).

MRI as "difference engine"

From the start, the TV program brought up the controversial dimension of the psychiatric MRI research on HIV patients at St. Göran's Hospital. Asked to give his opinion, Sääf first replied that "there are such strong interests when it comes to AIDS; there are both political and economic interests, and there are groups in our society who think that we should not treat patients that have been infected with HIV." Towards the end of the program, the reporter re-contextualizes MRI pictures of the HIV brains in their web of social consequences by getting back to the problematic aspects of St. Göran's HIV/AIDS research.[83]

Having gone through the brain images with Sääf, and having subsequently suggested a few speculative explanations of the HIV virus' effects on the brain, the reporter links again to the effects of HIV-induced brain damage on patients. She repeats that "very advanced testing methods" have enabled the researchers to prove that many HIV patients with brain damage exhibited reduced ability to concentrate, memory loss and reduced motor capacities, and interviews St. Göran's psychiatrist Birgitta Alexius—of whom she says: "Birgitta Alexius' words carry great weight. She often lectures for authorities about HIV patients' mental problems." Against a background of images of landing flights, train cabs, and power stations, the reporter explains that even though not all HIV-infected patients show brain damage or neuropsychological impairment, "St. Göran's results may lead to increased HIV-test requirements for pilots and train drivers; atomic energy workers with responsibility for many people's lives." The reporter points out that the main issue concerns those with MRI-demonstrated brain damage but no symptoms of decreased attention, capacity of judgment or motricity.[84]

Asked about her opinion, Birgitta Alexius argues for systematic testing of pilots-to-be:

> *Birgitta Alexius: I personally consider that when it comes to these professions where you are submitted to an extensive health control before you get into the profession—and this concerns for instance flight personnel, train drivers—then I think that HIV testing should be mandatory. This is my very personal opinion, it has nothing to do with what the National Board of Health and Welfare or any other instance thinks. It is my opinion that you should be tested before being accepted for long and demanding training in a profession calling for very sharp attention. When it comes to those who need to go through regular tests when they work, for example pilots who are a professional group much discussed these days, then I think that people should not be removed from their jobs as pilots but that the firm's physician and the treating physician should be in touch. It may take many many many years and nobody*

> *knows at all when there will be the slightest effect on the brain. But it can happen quickly.*[85]

Alexius thus argued for a surveillant medical gaze that would keep track of HIV-infected patients in their work settings—all in the name of risk containment. Subsequently, the reporter explains, Scandinavian Airlines (SAS) introduced mandatory HIV testing for their pilot training in 1987; in her own terms, "the message [from St. Göran's] has been heard." In contrast, the World Health Organization (WHO) considered in 1988 that it was not an established fact that symptom-free HIV-infected patients could have brain lesions; they therefore opposed routine testing of pilots. Pilots' organizations used the WHO's position in their protests against SAS policy.[86]

The reporter asks Jan Sääf, "But do you notice in the patients that they have brain damage when they arrive?", to which Sääf replies: "No. [---] In a large majority of cases you don't notice anything at all." "But the image looks really dramatic with its large red areas," the reporter insists. "Yes, that's true", Sääf replies, "but it is also true that we have a large spare capacity in the brain [---]." The reporter's final position is ambiguous: Although making Alexius acknowledge that the issue is controversial and leading her to a certain extent to contradict herself, and although confronting Sääf with the persuasive power of the rampant red dots in the brain scans and their limited predictive power, she concludes the program with the hardly critical following words: "Few flight companies HIV test at present, so SAS is quick off the mark."[87]

To judge from the TV program, the controversial influence of St. Göran's "brain images of HIV" was far-reaching and the basis of that influence uncertain. How may the power of these pictures be understood? In *Picturing Personhood* (2004), Joseph Dumit makes an analysis of the visual rhetorics of PET scans as they are produced in the lab, published in the media and used for advertising. The image cases he interprets from the media have a caption, usually one word per image in an implicitly comparative series of scans, such as: "Normal", "Depressed", "Schizo"; or "Normal control" and "Obsessive-compulsive". Dumit argues that when PET brain images leave the community of PET researchers (who usually know that these scans are "illustrative" of a research process rather than "veridictory" as a basis for the formulation of facts) and circulate in the media, something happens to their persuasive power: "PET images can sometimes become the main argument," he writes, "with the text as supplement. In the popular arena, in magazines, newspapers and on television, PET images become the principal message." [88] Dumit also shows that color-coding of images is part of these rhetorics—where hot colors (red, yellow) usually signify activity in contrast to cold colors like green and blue.[89] What Dumit thus points out is how medical imaging technologies become a focus of attention in themselves when leaving the laboratory, with a subsequent collapse of their contents and contexts, color schemes and reading frames into deceptively easily deciphered pictures of a disease or phenomenon.

The sensationalism occurring in the mediatization of MRI scans of HIV-infected brains works in a similar manner: On the one hand, the individual images of diffuse chemical changes in the brain tissue reflected St. Göran's ongoing research attempts to elucidate MRI images' relation to psychiatric changes and to characterize applications of MRI visualizations. In that process, what kind of differences MRI images demonstrated in individual brains was highly undetermined; just like the relationship between HIV infection and brain damage, or between induced brain damage and behavior. On the other hand, the scientific publications by Wetterberg's group, and their explanations in the media, built on a technoscientific aura of certainty: infallibility and objectivity. When placed in a media context, the MRI images of brains became "pictures of the disease" rather than situated and equivocal measurements.

However, Dumit also shows that the process of labeling scans—and thereby, brains and individuals—is of the same kind in the scientific and mediatic production of PET images, and that PET therefore functions as a "difference engine" in the laboratory as well. The production of difference through medical images takes part in the making of the "disease itself," Dumit argues:

> Significant [---] is the way in which, though the brain scans of the diagnosed normal volunteers are labeled *normal controls*, the brain scans of the diagnosed schizophrenics are labeled *schizophrenia*. The image is thus labeled as showing the "disease" itself rather than a correlate symptom of someone found to have schizophrenia.[90]

Dumit is therefore critical of the idea that the "disease itself" exists independently of our cultural frames of understanding and methods used to demonstrate disease. In the light of the above, MRI's working as a "difference engine" between normal/healthy brains and "HIV brains" appears to have two interdependent consequences. First, it enacted an epistemological relation between HIV-induced dementia, the individual bodies/brains/psyches mobilized in the research, and the methods used to produce facts about the disease (including their tangible result: MRI brain scans). Second, it facilitated the production and promotion of an unstable construct: HIV-induced dementia, a specific but diffuse and often invisible form of psychiatric condition that could however be used very concretely with MRI scans or neuropsychological tests in work policies like that of Scandinavian Airlines.

CONCLUSION: MRI'S ANATOMIZATION OF PSYCHIATRY

This chapter started under the auspices of the cerebral body, and asked the question of the use and influence of MRI in clinical psychiatry at St. Göran's. Here I shall discuss the relationship between MRI depictions, anatomy's gaze and notions of psychiatric illness before concluding with the MRI gaze that emerged in the clinical work of St. Göran's MRI group.

At the beginning of this chapter I introduced Robert Martensen's argument that the importance given to the brain in terms of who we are as human beings was a result of early modern physiologists' theories, methods and strategies of depiction in a changing cultural context of visual representations. In line with what Michel Foucault argues about the medical understanding of the body at large, anatomy became the privileged frame for the production of the *real*.[91]

Similarly, the irruption of the brain in St. Göran's psychiatry as described by Wetterberg marked the installation of anatomy's specific kind of real in psychiatry's diagnostic apparatus. I use the word "real" deliberately, because according to Wetterberg's narrative and his groups' publications, MRI made it possible to demonstrate and fix pathological causes and/or effects, in contrast to psychiatrists' earlier "guesses" to which Wetterberg and Larissa Bilaniuk referred (cf. Chapter 2 and earlier in this chapter, respectively). This "anatomization" of St. Göran's clinical psychiatry was performed in practice, viz., in the systematic production of MRI brain pictures, not least of demented HIV-positive patients; in the diagnostic interpretation of the patient cases; and also in the social organization of work, i.e. in the cooperation with radiologists.

In an article about the tropes at work in the clinical use of MRI, Kelly Joyce has argued that radiologists giving MRI agency (the agency of "showing" pathology, for example) lent authority to MRI scans. Similarly, in many of the short case reports published by St. Göran's MRI team, MRI was given agency: MRI "delineate[d] the tumor well", and most often "showed" affected areas, specific kinds of tumors and other morphological brain changes.[92] In the TV program "Knowledge of AIDS research", MRI was given the agency of a whole laboratory, analyzing millions of samples of brain tissue and interpreting them as normal or abnormal. Joyce's argument holds good for the examples drawn from research at St. Göran's: transferring authority from the researchers to the machine was not only an efficient way to visibilize the technology in order to acquire more funding, but also a way to assert a certain form of objectivity—what Lorraine Daston and Peter Galison have referred to as "mechanical objectivity".[93] This transfer of agency and authority to MRI was one element that contributed to the installation of radiology's anatomical real in psychiatric practice at St.Göran's.

The medical gaze at work through MRI scans and MRI examinations was in many ways similar to the radiological gaze studied in Chapter 3. Or, as Lars-Olof Wahlund puts it: "we examined and assessed the patients on radiological grounds".[94] At St. Göran's Hospital, MRI visuality was used to produce differences within and between images in order to view macrostructures within the brain. The brains produced with MRI were anatomical brains, just like any organ in the body. This is mostly true of the "routine" MRI examinations performed systematically on incoming psychiatric patients. (However, the case of MRI scans of HIV-infected brains nuances this interpretation and suggests that something more than anatomy was also at stake: MRI was used as a virtual laboratory—which Chapter 6 will consider in another context.) The MRI gaze at work at St. Göran's reproduced clinical anatomy's epistemology: it sought the visible marks of (psychiatric) disease in the materiality of the body/brain.

This anatomization of psychiatric practice may have been quite new at St. Göran's, but it was certainly not unique or even specific to Sweden. Rather, it may be read as part of a broader move that anthropologist T.M. Luhrmann, among others, has analyzed in American psychiatry: from psychoanalysis and psychodynamic psychiatry towards biomedical psychiatric science or "remedicalized" psychiatry in the 1970s and 1980s. Luhrmann writes:

> It was around this period, in the 1970s, that a new kind of psychiatrist began to emerge. These psychiatrists saw themselves as scientists, and to them that word set them apart from psychoanalysis, to which many of them were openly hostile and which few of them regarded as scientific. ([---] I will use the term "psychiatric science" to refer to this new movement in psychiatry.) The psychiatric scientists were committed to what they called strict standards of evidence, and they tended to view psychoanalytic theories of causation as neither provable nor disprovable by those standards. *They were determined to create a psychiatry that looked more like the rest of medicine*, in which patients were understood to have diseases and in which doctors identified the diseases and then targeted them by treating the body, just as medicine identified and treated cardiac illness, thyroiditis, and diabetes.[95]

On the impact of PET images' biologization of mental processes on patients suffering from depression, schizophrenia or other psychiatric illnesses, Dumit writes:

> The reconfiguration of mental illness as biological through the use of PET scans becomes part of a personal reconfiguration of one's own category of the person. A strict division between the biological self and the personal

> self is not at issue here. Rather, the relations between the two selves are redistributed so that although the patient must continue to experience the illness and live with it, she or he no longer has to identify with it. The diseased brain, in this case, becomes part of a biological body that is experienced rather phenomenologically but is not the bearer of personhood. Rather, the patient who looks at his or her PET scan is an innocent sufferer rationally seeking help.[96]

More than any other Swedish MRI-research group in the 1980s, the St. Göran's psychiatrists emphasized the individual human significance of MRI images for the patients. By identifying some causes of psychiatric illness as somatic, MRI also helped transport these causes outside the domain of responsibility of the patients and/or their relatives. Clinically speaking, MRI probably did not mean as much to the patients whose psychiatric condition could not be explained by neurological, organic causes—although Lars-Olof Wahlund's words tend to qualify that interpretation: "As in these cases and in many others," Wahlund et al. pleaded, "it may be of value to *the patient's family to be given an explanation of the origin of the mental symptoms and thereby reducing the risk of self-reproach*. Even a negative MRI finding which rules out somatic disease can in many cases prove very valuable and reassure the patient." [97]

However, the brain images Dumit studies, PET scans, are of a different kind from those under scrutiny here: they are produced as images of brain activity and therefore thought to give access to mental processes; in contrast, the 1980s MRI scans produced images of anatomy with less direct and less powerful associations to the patient's mind or thoughts. Rather, what Dumit points at that is of interest here is that brain scans, when they work as "pictures of the disease", play a role similar to categories of mental illness in the sense that they affect individual negotiations of personhood or self.[98] Besides, PET (and MRI) scans—although to different extents—reconfigure mental illness as biological: PET by making thought processes biological; and MRI by making anatomy the frame on which mental illness (such as HIV-induced dementia) can be produced, identified or visualized.

If with MRI, psychiatrists were looking into the brain anatomy of psychiatric patients, was MRI then reinforcing a biologistic understanding of the mind and its diseases? Paradoxically, the answer is no, at least when it came to the systematic MRI examinations conducted in search of organic diseases such as tumors. Rather, the clinical work conducted at St. Göran's reinforced one step further, with technological arguments, a traditional separation of body and mind, of the brain and the soul. MRI was used to identify the "wrong" psychiatric patients, i.e. the patients who needed surgery and not psychiatry. By excluding from psychiatric treatment the patients whose illness did not have a psychic origin but rather an "organic" (i.e. bodily) pathological cause such as a tumor, Agartz, Wetterberg and their colleagues delineated more strongly the domain of the psychically abnormal and extended the domain of the psychically normal. Reaching within the body to draw that line reinforced a neurological gaze; but at the same time it contested it since the remaining abnormal behaviors (those which did not have an organic cause) were kept outside the organically explainable phenomena, out of reach of the neurological gaze.[99] In a sense, MRI acted as an invisible hand that sent the brain back to the body and let the mind escape the medical images.

Luhrmann's position on the biomedicalization of mental illness is dual. Whereas she acknowledges both biological-scientific and psychodynamic perspectives as helping to relieve suffering caused by psychiatric conditions, she warns against the dangers of an all-biologized understanding of mental illness. Not only that, she also emphasizes the dangers of a pervasive "vulgarized" medical understanding of illnesses that are in general, like schizophrenia, poorly understood:

> [T]here is also a moral danger that lies in the way we see patients and the way they see themselves. The popularized, vulgarized medical model invites us to see the mentally ill as not quite human, particularly if their problem is chronic and unremitting. [---] to say that someone's reasoning and feeling are diseased, when the disease never goes away, is to say that she is not fully human. In the vulgarized biomedical model, the mentally ill have been struck by something that came in from the outside. It was not under control in the first place, and remains no more under control than a doctor can control it.[100]

Still, it would be misplaced to put the blame on popularization and vulgarization as such, or on the media alone. Dumit emphasizes the "multiple accountabilities between the diverse communities engaged with PET," not least the lay persons who also actively invest brain scans with complex meanings, caught in "theory transfers" through "all kinds of mediators—movies, magazines, personal physicians, and anthropologists." "[C]ontemporary biomedical and scientific practices are culturally situated," Dumit reminds us, and facts travel and change as brain scans travel in different social and cultural contexts.[101]

The issue of accountability in the production of facts and meanings is all the more relevant since the MRI gaze as enacted at St. Göran's Hospital was distinctly surveillant, in their screening work, and with consequences for the AIDS policies established on the basis of evidence of HIV-induced neuropsychological impairment. On radiological screenings as instruments of a surveillant gaze, Lisa Cartwright writes:

> I return here to my claim that the public culture of prophylactic imaging that emerged around the mass X-ray screening campaign against tuberculosis constituted the emergence of a double-edged public gaze. I characterize this gaze as surveillant, but I do not suggest that surveillance is by necessity a totalizing mode of institutional domination and control of populations. I describe this gaze as a mode of perception whose agents are not only or primarily physicians and scientists but also imaging technologists [...], patients, and medical activists.[102]

MRI itself did not introduce surveillance in St.Göran's practice, but I suggest that what took place was an alliance in practice of a visual technology ("the camera") and of existing cultural apparatuses of surveillance proper to psychiatry and to AIDS control.

Whereas this chapter has focused on psychiatry's identification of pathology with MRI, the next chapter addresses MRI research on the normal brain conducted at St. Göran's. There I shall explore further the intertwining of psychiatry's gaze and the open-ended MRI gaze: How did MRI scans make sense within the frame of psychiatry? How were psychiatric notions of the normal produced through the MRI gaze?

Figure 18. Frame picture from a Youtube video showing a (filmed) color display of MRI of the knee.[1]

interlude

reworking my own MRI body

Philosopher Ian Hacking writes that conceptually, “representation” comes before “reality”. In other words, what is culturally referred to as reality (as in “reality out there”, referent) is a product of the logical relation produced by the notion of representation: representation *of* reality. In the case of MRI, the reality out there (or rather, *in* there) is hence produced as a reality to be revealed, and one whose revelation may only be achieved by a radiological gaze using imaging technologies.[2]

Disclosure and display articulate relations of power: between the active individual observer and the body observed, but also between a gaze and the bodies submitted to it—and produced by it.[3] In other words, the individual body is positioned as an object of knowledge for radiology’s medical and cultural gaze. Lisa Cartwright has rightly pointed out the need for writing other kinds of histories that would give bodies back their agency over the cultural apparatus of the radiological gaze.[4] The as yet subjugated history of MRI would have to begin not only with experiences of MRI but also with individual actions on the MRI:zed body. YouTube videos of MRIs provide materials and examples of what such a history could bring out.

One MRI subgenre of YouTube videos is the montage of brain MR images obtained by the patient after examination. The montages are with or without music and come with or without text, and knowing that the very person "behind the brain" has put her/his MRI brain on display evokes disturbing feelings of fascination, interest, empathy—or simply, a curiosity which it is hard not to judge as voyeurist. By putting their brains on display, many users communicate important dimensions of their identities. For instance, "benchilada" writes about the silent MRI images posted as a video giving the impression of getting deeper and deeper within his brain:

> These are the images I got when I had my brain scanned via MRI.
> http://*****/fuckbrain [link to his blog]
> It was done because I have Tourette's Syndrome, OCD, Bipolar Disorder, et al. I think the images were to disprove the existence of Tiny Evil Gnomes burrowing away at my gray matter with Very Tiny Pickaxes.[5]

Through brain images, benchilada links to his own blog with further reflections, comic effects and dialogues about what he calls his "fuckbrain"—meaning dysfunctional brain. The display that he enacts is actually public: his video had been viewed by other users 2103 times by May 21, 2007. "Brain images of mind", as Joseph Dumit puts it, may provide a patient with a way to define psychiatric syndromes and/or disorder as entities separate from her/his own personality, and thus to reconfigure identitary boundaries to responsibility/guilt and possibilities of action. In other words, brain scans are part of individual reconfigurations of the "objective self", i.e. one's set of facts—scientific or else—about oneself.[6] Putting "fuckbrain MRI" on display may be part of such negotiations, and also allows one to set one's own brain in a further context of other forms of meaning production (blog diary, comics etc).

In a different style, an important part of YouTube's MRI-related videos align with existing diary genres, where somebody films themselves and tells about significant events of their daily lives. Authors of such videos articulate thoughts and feelings about not only the MRI examination they have undergone (which can be long, frightening, uncomfortable) but also what they saw on it.[7] A striking example—also viewed by many YouTube users (1824 views by May 21, 2007)—is that of "mtrcycllvr" (Eric) who posted his own film comment about his knee MRI there.[8] Eric writes as a presentation text:

> This is the unexpected result of simply asking for a copy of my recent MRI of my knee. I expected to get a film like I'd been shown in the doctors office, but when she asked, "Do you want that on CD?", I automatically said yes, thinking I was going to get a series of JPEGs or some such.. But nooooo… It's WAY better than that!

Eric's video itself begins with a silent slide reading "My Knee! In "MRI Vision" in golden letters. Then a computer screen is shown, Eric's hand is visible every now and then; his offstage voice tells the story of how he acquired the MRI images and program and comments on what is shown on the screen:

> *But look at the cool stuff this is doing! Those are such nice renderings of my leg! […] There is other stuff you can do with this like this top-down [screen view changes to horizontal cross-sections of the knee] through the knee-cap into my…no actually, this is from my foot working its way up.*

Eric adjusts the contrast on the image ("which is pretty nice", he comments), points with his finger to different places on the vertical cross-sectional image of his leg which he attempts to identify, and makes the images scroll in depth: every image is replaced with a deeper "slice" again and again.

> *And let's just scroll through here down deeper and deeper and deeper.*
> [Stops] *OK, there is really my knee cap now. Tatadadum!*

Eric comments his search for the knee cap within the layers of images as if he were commenting on a fascinating trip punctuated by his finding of the knee cap and later on, by switching to another display—his bodily landscape in three dimensions:

> *So, here's the cool part of this program, you can do all these cool views of stuff, but not just in two-dimensional like this. You can, you can ask for a 3D-volume-rendering, tchickching!*

Traveling in the human body is a "persistent cultural fantasy" that Kim Sawchuk coins as "biotourism", which she argues is "contingent upon the representation of the body as a frontier with glorious vistas that can be visited – perhaps not by a real body, but at least by the human eye."[9] This fantasy, just like Eric's traveling through his own leg, is based on the bodily *intervention* that any imaging device implies, Sawchuk argues ("jostling the subatomic protons in a body to create the MRI effect"). And still, the biotouristic utopia is that of not intervening (just as in mummy imaging): "one can voyage into the interior space of the body *without* intervening in its life processes, with silent footsteps, without leaving a trace."[10]

And it is not only the possibility of being there within the body, but also that of manipulating the visual architecture of that own body that is fascinating. Sawchuk writes that "[p]opular images and narratives of inner sublime space concretize our continuing faith in the phantasmagoria of progress and the body as the new frontier for high-tech exploits and interventions". As if in echo, Eric seems fascinated by the possibility of not only watching MRI as images ("a series of JPEGs", in Eric's words) but manipulating them in space and changing the texture of the bodily landscape as navigating through his own MRI:zed body. For example, commenting on the image shown here as Figure 18, Eric says:

> *Isn't that just cool?!* [points at the muscle section of his leg on the screen] *And look at how…doesn't this look just like a steak? Let's try a different color…* [changes color scale from gray scale to a red-yellow-white scale] *…yeah, this really looks like…like a good steak, yeah, yeah baby…*

When navigating "inside" his MRI knee and pointing and commenting on it, Eric relates to what the doctor saw and showed: "one of these [images] he [the doctor] said had showed a good view of my ACL [...], so that was in good shape." What Eric tries to relate to each other is not only the MRI scan and the doctor's interpretation, but also his own attempt to read the image himself: "I don't know how you tell a good shape, I mean. Looks broke to me..." At the end of the video, Eric finally shows the viewer what he thinks the doctor saw: "So...this is the view...where he pointed to...[...] he pointed to that black triangle here, and said there is something missing. Eh... [*laughs*] I think it's just because he had that piece of film and maybe he looked at the same thing I did and just saw that tear to that other image."[11]

Moreover, Eric sets his own body in relation to the images. When displaying a 3D sample of the region around his knee, he explains:

> *See this big dark spot right there? […] When I wrenched that piece of the bone* [points at a lot of different places in the image, partly obscuring the MRI scan] *out of the socket, and it tore that. […] And when I put some compression on my leg* [his hand moves and mimics the movement], *it hurts really bad right there* [points on a specific part of the image]. *But if I just leave it alone and walk gently, it works OK.*

Eric thus projects into the MRI knee the strain to which he submits his leg and the pain that comes from that; in displaying his "cool" MRI data he actually makes his suffering and his own efforts to negotiate it public.

Being endowed with the power of viewing his own body, reading images as he thinks the doctor did, and manipulating the bodily landscape they constitute is an experience transgressive to the social order of expert knowledge—which Eric expresses as:

> *And, man, can you believe i'm doing this at home on a home PC?! Who, who would have suspected that kinda…craziness??*

The display of the inner body and the intimate meanings of it at stake in these examples is thus different in kind from the radiological gaze's authoritarian disclosure of privacy: By re-mediating their own private MRI scans, taking on themselves powers of viewing, interpreting and narrating the scans, and setting them into context, these YouTube users take back forms of agency over the radiological gaze and can enact a re-working of the objective meanings of their own MRI bodies.

[5] quantifying normal anatomy

brain MRI research

The MRI-scanner was purchased on the fringe of the ordinary ways, and the goal was to use it for psychiatric brain research. At that time, it was difficult to get our psychiatric patients even clinical CT examinations; there were fewer CT scanners available at that time and psychiatric patients were not on the priority list unless they had symptoms or signs of tumors, bleeding or a neurological disease. Back then, psychiatric patients were a low-priority group in health care. Psychiatric patients did not have high prestige, and psychiatric disorders did not have high prestige. Nobody would just come forward and say "Yes, I have schizophrenia." That's why it was so important for us to obtain excellent methods to study patients with psychiatric disorders.[1]

Psychiatrist Ingrid Agartz, from interview (2005)

introduction: normal brains in neuroscience imaging

The previous chapter explored how Wetterberg's group used MRI clinically in their psychiatry department, the ways in which brain anatomy was mainstreamed through MRI in parts of their diagnostic work and the power as well as the shortcomings of anatomic brain depictions in their practice of psychiatric diagnosis. However, MRI was not only used in diagnostic practice; as Ingrid Agartz's comments indicate, MRI examinations also created "materials" facilitating long-awaited clinical research on the relation of brain anatomy to major psychiatric disorders.

This chapter examines another aspect of psychiatrists' MRI work at St. Göran's Hospital: their research on the *normal brain* with MRI. My intention is twofold. First, I want to nuance the picture given in Chapter 4 and show a very different side of psychiatrists' work with MRI. Second, I want to explore how MRI-based brain research linked together issues of visuality and of methodological objectivity in the production of psychiatric-anatomical facts through an MRI gaze.

To put it plainly: whereas Chapter 4 focused on how MRI anatomy entered psychiatry, the present chapter addresses how psychiatry's frames of knowledge were made to permeate MRI brain anatomy.

Although not new in psychiatry in general, the neuroradiological (brain-radiological) approach to the study of mental illness was a new opening for the St. Göran's MRI group. The group focused on "fundamental questions" about psychotic disorders (including schizophrenia) and, soon, dementia. Alcohol abuse was a third category of disorder that the St. Göran's group studied with MRI. Agartz explains that their "purpose was to see if we could learn more about the psychiatric diseases in a biological perspective," which meant more specifically to obtain "new information that would help us understand the etiology [causes] of diseases," and give access to the functional changes induced by these in the tissues of the brain ("pathophysiology").[2]

Wetterberg's group used two main MRI-based approaches, Agartz explains in our interview:

> *But the valuable part of MRI at that time was that we were not limited to visualizing the brain. MRI is not only an anatomical visualization method – that's a part of it – but one could also measure different biochemical tissue characteristics directly in the images. At the time, it was possible to measure the magnetic relaxation time constants, which we started to do. In my doctoral work, I measured the relaxation times in discrete brain regions – from the images – to investigate whether characteristic brain*

> *changes could be demonstrated in patients with different psychiatric disorders in comparison with healthy control subjects.*[3]

First, they used visual methods to assess deviations from normal brain anatomy: Were certain areas in the brain larger or smaller in different patient groups as compared to control persons? Second, the St. Göran's group attempted to find correlations between quantitative MRI measurements of brain tissue and different psychiatric disorders. Whereas the former approach was inscribed in the *continuity* of existing international psychiatric research called morphometric studies in which brain areas had been assessed with CT, the latter marked a *rupture* with visual, anatomical approaches to psychiatric diseases and a shift towards a more laboratory-inspired approach to the body (brain). This chapter is organized along these two lines and explores, first, the visual methods used to assess brain anatomy and, second, the quantitative laboratory-like strategies developed for brain studies with MRI.

This clinical *research* was different in purpose and methods from the diagnostic use of MRI analyzed in the previous chapter: St. Göran's MRI-research work aimed at finding and interpreting characteristic features (morphometric and NMR-quantitative) for diseases as compared to the normal brain, rather than establishing diagnosis and choosing treatments for individual patients. In short, Wetterberg's group found that the size of certain brain regions (cerebrospinal fluid spaces) was larger in patients with acute psychosis, alcohol abuse or dementia than in healthy controls. Further, they showed that the MRI characteristic T_1 was different in the brains of psychotic patients, alcohol patients and demented patients from T_1 in those of healthy controls. Neither the size of brain areas nor the values of T_1 were specific for one condition; but combined information about T_1 and size of brain areas enabled a rather good discrimination between different conditions.[4]

In their attempts to characterize the pathological, Agartz, Wahlund, Sääf and Wetterberg had to handle the variations they observed in the domain of the normal. A large part of the efforts that St. Göran's MRI researchers deployed were thus directed towards the characterization of the normal brain with the new MRI technology: What was a normal brain like, and where were the limits between the normal and the pathological?

In her study of brain mapping with PET, anthropologist Anne Beaulieu has shown how brain atlases constructed with brain-imaging technologies *produce* notions of the normal brain. In her chapter about the production of brain atlases, Beaulieu emphasizes that the "normal brain" does not have a fixed definition, the concept instead being the product of such

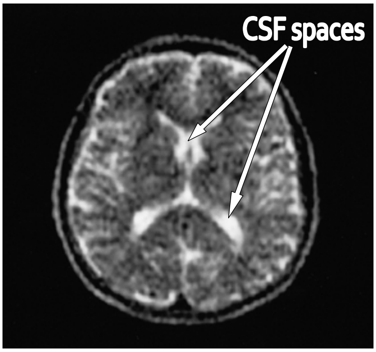


Figure 19. CSF spaces on an MRI image of the brain.
On this MRI scan, the CSF space is represented as bright areas; those are found in the central regions of the brain. (Arrows and text added).

technomedical practice. One issue that has been discussed in neurosciences was that of deciding which brains, and more explicitly, *whose* brains, were to be considered representative of the normal. A reference atlas produced in the 1950s and re-actualized in the 1980s was the Talairach atlas, made of anatomical depictions of one hemisphere of the brain of *one* woman in her sixties. Thus one individual brain was set as a norm against which other brain anatomies were compared. This way of defining the normal was replaced in the 1980s by atlases that averaged brains (i.e. brain images/data) in socially homogenous volunteer groups and, in the 1990s, by statistical brain maps making it possible to define and quantify "probabilistic" differences between groups of individuals—positioned in this statistical map by social variables such as sex, race and age.[5]

Beaulieu thus shows that brain atlases evolved from performing a "characteristic" representation of the normal brain (Talairach's atlas), through a notion of the normal as average, towards that of the normal as a probabilistic model dependent on a digital-statistical frame. She also shows that the changing notions of the normal are dependent on broader neuroscientific and medical paradigms, such as the interest in difference between individuals and groups in the late 20th century's era of genetic studies of the brain. Further, she shows that notions of the normal are intrinsically dependent on the methods used to produce them, which in turn are entangled with concerns about objectivity and judgment in the comparison and statistical processing of different brain scans.[6]

As a part of their research work, Wetterberg's group attempted to characterize the normal brain from the brains of healthy individuals. Not unlike the neuroscientists in Beaulieu's study, Wetterberg's group had to develop tools that would enable the comparison of brain scans. In this process, they built notions of the normal into the technological-visual apparatus. This chapter is a close analysis of selected aspects of their research and aims to explore the methods used in their work with the normal brain: Which classification tools did Wetterberg's group develop and why? What was a normal MRI brain? How was the MRI gaze made to articulate psychiatric notions of the normal?

SEEING: TOOLS OF OBJECTIVE VISION

visual rating scales: disciplining the observer's judgment

Would you expect the brain of an 82-year old to be the same as that of a 27-year old? In their MRI-based research work, Wetterberg's group soon defined the issue of characterizing normal ageing of the brain as central to their analyses. In an extensive review article published in 1988, neuroscientist and radiologist Burton P. Drayer wrote that "[t]he diagnosis of disease in elderly patients is often complicated because alterations in brain structure and function may occur normally. There is a surprising lack of clinical, radiologic, and pathologic information regarding the normal aging process in humans." [7]

The depathologization of ageing, i.e. the definition of ageing as a normal process which did not cause death by itself, began in the mid-twentieth century, according to historian of medicine David Armstrong, who writes:

> One attempt to solve the problem of distinguishing pathology from aging, suggested that aging, like life itself, should be divided into normal and pathological. In effect there had to be a pattern of aging that was free from all attacks of disease.[8]

Drayer argued that the understanding of ageing took a new turn with the appearance of advanced brain-imaging technologies. He wrote that the introduction of computed tomography (CT) in the 1970s had catalyzed studies of ageing in the brain "*to analyze the limits of normalcy in healthy, elderly individuals*" in the second half of the 1970s and in the 1980s.[9] Ageing was by the 1980s a fundamental dimension of defining what a normal brain was for neurologists.

Studies conducted with CT and MRI as well as postmortem studies had showed that two kinds of changes commonly happened with age: on the one hand the enlargement of the cavities of the brain containing the cerebrospinal fluid (CSF) (see figure 19), together with a shrinking of certain brain areas; and on the other hand, the apparition of "white matter lesions" (WMLs), i.e. lesions in the white matter of the brain.[10] Still, by the mid-eighties none had explored whether there was a relationship between

Table 4. The scored single and cluster items

1. The size of the lateral ventricles
2. The width of the interhemispheric fissure (anterior to the corpus callosum)
3a. The width of the right Sylvian fissure
3b. The width of the left Sylvian fissure
4. The width of the occipital sulci
5. The width of the frontal sulci (lower frontal region)
6. The prefrontal CSF space (the size of the CSF space in the prefrontal cortical area)
7. The presence of periventricular white matter lesions
8. The size of the subarachnoid cisterns (the superior cerebellar, the magna, and the ambient cistern)
9. The amount of CSF around the cerebellar hemispheres
10. The width of the parietal sulci (superficial sulci, primarily in the parietal and upper frontal region)
11. The presence of white matter lesions with non-periventricular localization

21. The frontal CSF cluster (items 2 + 5 + 6)
22. The temporal CSF cluster (items 3a + 3b)
23. The global CSF cluster (items 21 + 22 + 4 + 10)

Figure 20. List of "items" defining a discrete brain topography.[11]

these two common changes. For example, could it be so that lesions appeared more often in areas close to where the CSF spaces had expanded?

On the basis of MRI examinations conducted from 1985 onwards, Agartz, Sääf, Wahlund and Wetterberg, together with neurologist Olle Marions from Södersjukhuset Hospital, investigated whether there was a relationship between the enlargement of CSF spaces and the appearance of WMLs, and in which way these phenomena were dependent (or not) on age and sex.[12]

Although it did not show any correlations that had not been reported before, this study is interesting to me because of the methods developed to establish a standard description of brain spaces. Agartz and her colleagues wrote that they developed a "visual rating scale" to quantify their assessment of the size of brain structures. That quantitative scale was based on their daily observations of brain scans, which they referred to as "subjective judgments":

> Visual estimations based on subjective judgments are commonly used to evaluate MR images in the daily clinical practice. Before the current scale was developed, it appeared that from the wide range of brains in healthy individuals that had been inspected, it was possible to divide the brains distinctly into three different categories based on the width of the subarachnoid and ventricular space. The

> standard reference unit was defined as the category with small and narrow sulcal and ventricular width (score number 1). When in practical use, the CSF spaces in subjects in their 20s and 30s were usually rated as 1, and older subjects in this population were small enough to be rated either 1 or 2. Few individuals were rated 3 for any of the items [i.e. areas assessed]. [13]

The visual rating scale was quantitative but simple: First, the theoretical brain was divided in a discrete series of "items" to be assessed. For example, Figure 20 reproduces such a list of items, which were defined as "size of the lateral ventricle" or "width of interhemispheric fissure", or the presence of WMLs around the CSF ventricles. Second, for each item to be assessed two "raters" from the researchers' group gave a score 1, 2 or 3 without consulting each other. The score 1-3 signified either the size of a CSF space (1= small and narrow: "size of cisterns"; 2>1; 3>2) or the presence of lesions (1=not present; 2=single focal lesion; 3=multiple focal lesions). Hence 1 represented the normal, and 2-3 deviations from the normal, with 2 milder than 3. For each brain scan assessed, the set of scores from the two raters were averaged with each other, creating a less subjective set of scores for the specific scan. The resulting method was a "rating scale developed for the quantification of subjective visual estimates of the size of the CSF spaces and the occurrences of WMLs".[14] (This visual rating scale was also used in further studies in the 1990s.[15])

The development of visual rating scales is a sign that the subjectivity of judgment involved in seeing the brain with MRI was acknowledged as necessary in the interpretation of scans *and* as problematic since two observers could make two different interpretations. I therefore want to argue that visual scales were thought to be a good way to discipline the subjectivity of individual seeing. The problem seemed to be not so much subjectivity as such, but rather, observers' idiosyncrasies.[16]

The augmented objectivity of the interpretation of the scans was thus not so much the result of a quantification of the subjective, visual judgment of the observers, but rather the effect of the possibility of averaging two such judgments. The role of quantification with scores from 1 to 3 was to make this averaging possible. Interestingly enough, different observers read the images in quite a similar way: 80% of the items were scored similarly by their two raters, and in 96% of cases "the raters rated equal or in the same direction." [17]

The brain in this study (the researchers' "working object") was thus a collection of items, i.e. a collection of questions to which the answer was 1 to 3. The items that constituted this space were also "clustered" into larger items, aiming to answer the question "What is the size of the whole frontal CSF space?" independently of the assessment of the smaller CSF spaces.

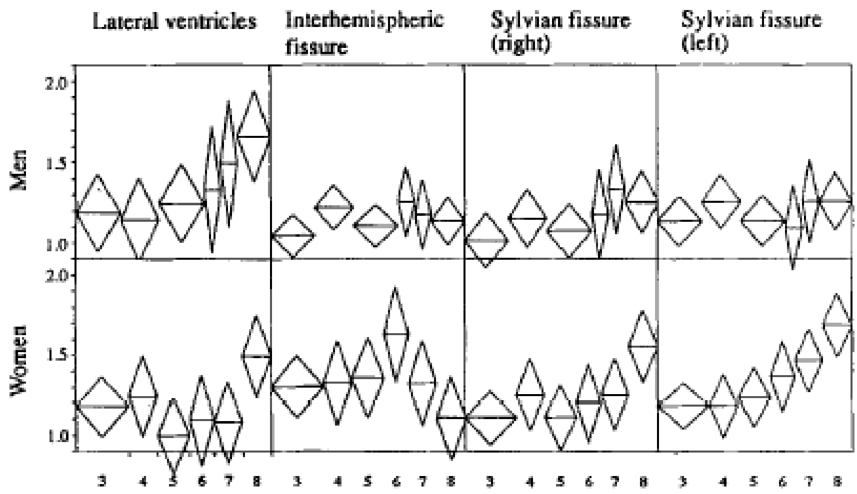


Figure 21. "The normal brain": Mean values (1-3) of four morphological items plotted against age in men and women. The horizontal axis indicates the decade of life (age). For instance: "4" means subjects in their fourth decade, i.e. age 30-39. The mean values (1-3) are plotted together with the statistical variance (triangles).[18]

The set of items/questions reflected a visual logic, a gaze trained at targeting specific spatial objects, such as the size of a space, or high T2-intensity areas revealing a white matter lesion. Further, the visual logic at stake was that of radiology's and anatomy's *bifocal gaze,* as sociologist Amit Prasad calls it: a gaze that on the one hand identified localized anatomic elements and on the other hand, re-situated them in a whole-brain map (cf. Chapter 3).[19] Whereas the "single items" reflected the former dimension of this gaze, i.e. the local isolation of structures/changes, the "clustered items" executed the latter function of that gaze: that of organizing and localizing elements in the whole.

So the items that constituted the brain of this study worked as questions which corresponded to the visual interpretation of anatomy in radiology. However, the answer to these questions—the score of the item—was quantitative. The set of items may therefore be understood as a textual/quantitative translation of radiology's visual gaze. The intelligible brain was what emerged through this set of items, which worked as a topographic grid.[20]

But what was the normal brain thus produced? First, the normal brain was statistical. Figure 21 shows a graph summarizing some of the results of the study under scrutiny here. This graph is divided into eight smaller graphs which look like boxes, corresponding to the respective visual scale results of four items ("lateral ventricles", "interhemispheric fissure", etc.) plotted separately for men and women. In each of these boxes, the mean values between 1 and 3 of the item are plotted against age of participants; the 3,4,5,6,7,8 axis indicates the decade of life, i.e. age (for instance: "4" means subjects in their fourth decade, i.e. age 30-39). Still within each box, the mean value (1-3) corresponding to a decade is plotted as a short horizontal dash imprisoned within two triangles representing the statistical variance of the results.

The "normal" brain, as represented by the graph in Figure 21, was thus not a picture of what a brain should look like; it was a set of average results with statistical margins on the topographic grid of items. Symptomatically, the pictures in the article reporting this study were all graphs; not one MRI image was published. Further, the quantification of subjective features into the 1-3 scale permitted the study of statistical differences between age groups and between sexes. The normal brain was thus a set of probabilities of being in the average range of the topographic grid depending on age; and normal ageing was sex-differential: the ageing of the brain seemed to depend on sex, beginning earlier in men (cf. for instance the two boxes on the left in Figure 21).[21]

Second, whose were the brains out of which this normal topography was built? How normal did you have to be to get into the normal group? Joseph Dumit writes of similar problems in PET researchers' experimental design:

> Defining criteria for participant inclusion requires delimiting the boundaries of "normal human" for purposes of the study. Is a chronic smoker or coffee drinker normal enough? How about someone who had been found to have depression 10 years ago and has taken Prozac for 6 months – or someone whose brother is schizophrenic? [22]

Wetterberg's group defined the normal as inclusive of variations encountered in the broader population; and they mentioned explicitly the factors for which they considered the normal group too homogeneous—for example as regards the socioeconomic conditions of the individual under study:

> Most volunteers were recruited from hospital personnel and their friends. They all belonged in the middle and upper socioeconomic strata and lived in an urban environment. The ethnic background was Swedish except one person who was French of descent. All volunteers reported themselves to be healthy. At closer penetration of the disease history, a few individuals were found to have diseases that might affect the central nervous system [i.e., brain and spine]. *The reason for accepting the inclusion of these subjects was to avoid a too heavily selected group.* The assumption that samples of "control"

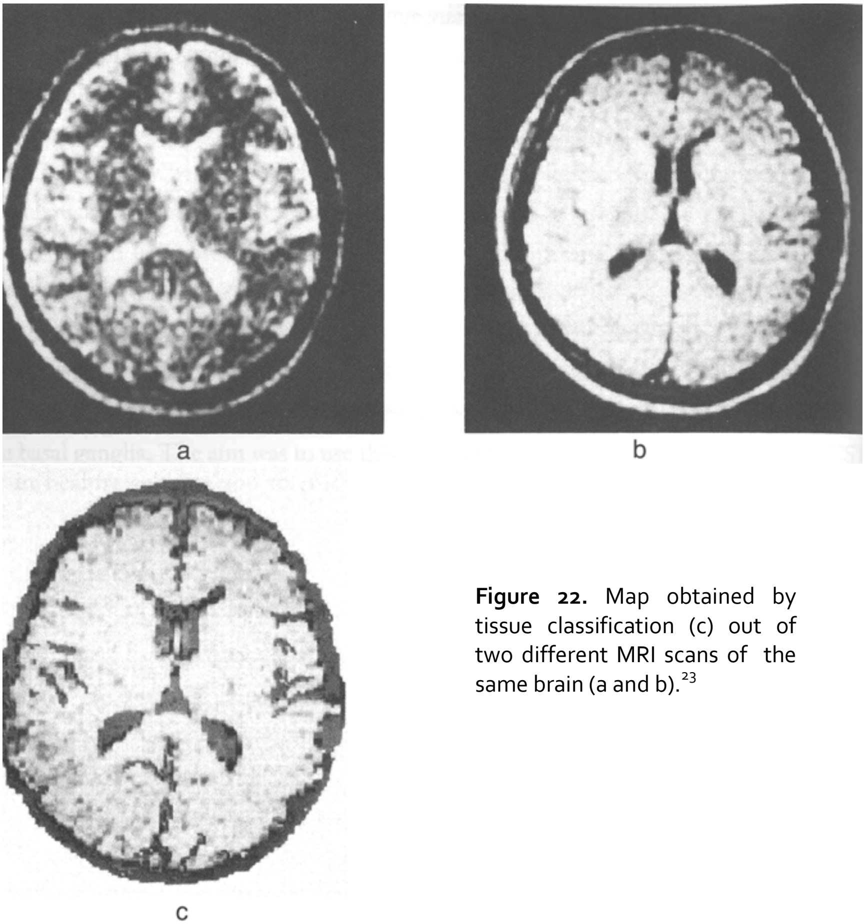


Figure 22. Map obtained by tissue classification (c) out of two different MRI scans of the same brain (a and b).[23]

> subjects from radiology files may have smaller ventricles than healthy volunteers and that this may truncate distributions has been made by Andreasen and coworkers [...]. Substance abuse was an exclusion criterion in the present study.[24]

That definition of the normal was rather wide, in part because earlier radiological studies had proved to be biased because of the "supernormalcy" of the control groups. However, it shows which parameters were usually taken into consideration in psychiatric studies, and which were expected to be relevant to the normal/pathological state of the brain in the MRI study: socioeconomic factors, life environment and lifestyle, family diseases, and, as reported in another section of the study, somatic diseases, handedness, alcohol consumption, weight (body size) and ongoing medical therapies.[25]

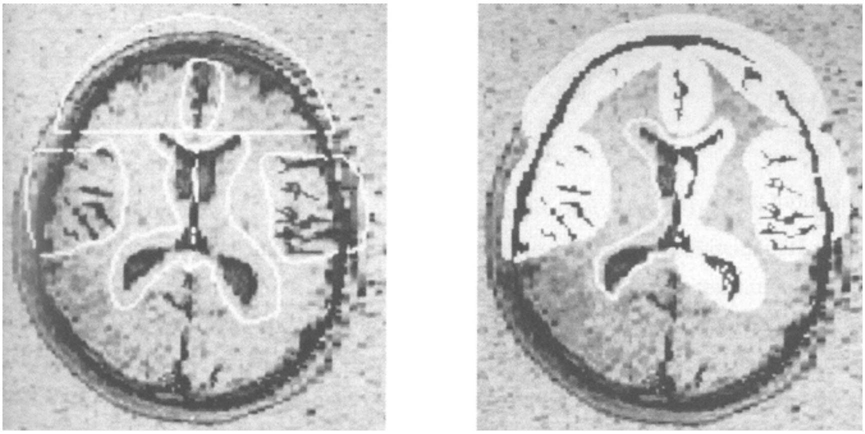


Figure 23. Outlined regions of interest (left) and counting of brain and CSF spaces area, respectively (right).[26]

The topographic grid of the normal brain was thus not translating scans into data in a void; always implicitly present in the normal brain, i.e. in the average values on the item grid, were the cultural coordinates of the individuals on which it was calculated: bodily, social and economic conditions. The brain topography thus constructed was a *system* that linked individual brains (as research material) to this statistical grid.

beyond subjective assessment: computerizing measurements of brain areas

A further step in quantifying brain structure, i.e. in constructing quantitative topographies of the brain, was taken "to assess the accuracy of the visual rating scale".[27] Agartz, Sääf, Wahlund, and Wetterberg developed automatic procedures to measure the size of brain areas against that of cerebrospinal fluid (CSF) spaces.

The method developed by Agartz and her coworkers was built on "tissue classification", i.e. the procedure classified automatically all the pixels of the MRI scan of somebody's brain into either brain matter or cerebrospinal fluid. Figure 22 shows two different MRI scans of the same brain and, below, the resulting image obtained after processing: the classified picture resembled a map filled with areas in either of two colors: a bright one for brain matter, and a darker color for CSF.[28]

Figure 23 reproduces the published illustrations of a further procedure, that of the counting of the size of brain areas. The picture on the left in Figure 23 shows a classified, "mapped" MRI scan on which bright lines have been computer-drawn by a researcher. The picture on the right displays a similar classified image with filled shapes that correspond to the lines drawn on the left picture. The publication from which Figure 23 is taken explains that one of the researchers delineated brain areas of interest by hand on a classified scan, through a computer. With an additional step of computerized image processing in which the number of brain-matter pixels and the number of CSF pixels were automatically counted in the outlined areas, the researchers obtained a measure of the size of the brain areas of interest.[29]

The automated procedure, executed by the MRI scanner coupled to a computer designed to process pictures, thus acted both as a "mapper" (transforming the brain scan into a map of brain matter and CSF) and as a "counter" (giving a quantitative area measurement of specific brain areas). The quantitative results could then be interpreted with respect to the individual's sex and age.

Agartz and her colleagues performed and validated this counting method on over 70 healthy volunteers. The results validated the method by confirming what was already known about the ageing brain:

> The applied method is valid and reliable in the discrimination of different biological tissues. It proved to be useful to discriminate brain tissues from cerebrospinal fluid in MR images. [...] the results at large were in accordance with expected findings in regards to differences in age and sex in the healthy population. In the current material sex differences were different depending on the age of the subjects, which underlines the need to consider both age and sex in the assessment of intracranial dimensions.[30]

However, one problem was now how to compare the brains of different people within the study: each brain had a different size. Moreover, men's brains were found to be larger than women's; so were also specific areas in the brain. But men were on average taller than women, so their skulls would also be larger than women's. A first "normalization" of the results was therefore to average brain surface with body size (approximated with body mass index, BMI). Instead of comparing absolute surfaces of the brain and of specific brain areas, the researchers would work with ratios of surface/body size. Nevertheless, the difference between men as a group and women as a group persisted after this first normalization: even after having "corrected" the results for body size, men's brains were larger than women's (i.e. a man would statistically have a larger brain than a woman of the same body size and weight).[31]

But what about the different areas within the brain? To be able to explore possible differences between individual brains, and build statistics on groups such as male and female brains, Agartz and her coworkers normalized their results one step further. Instead of working with absolute pixel numbers for specific brain areas, they worked with relative sizes: size (number of pixels) of a specific area divided by the size (in pixels) of the whole space inside the skull. It was on these normalized areas that the final statistics were calculated. After this normalization, Agartz and al. found no difference between men and women's brains: Their structure and proportions were significantly similar.[32]

This shows that the *differences* produced through definitions of the normal brain were intrinsically dependent on which variables were integrated in the calculations of a measure defined as characteristic (here, the size of brain areas). Further, this had in turn a bearing on which *kinds* of difference (such as sex) were produced as relevant for defining a group—or dismissed: In the case referred to above, sex was shown to influence the absolute size of brain regions but not to be relevant to the chosen measure of normalcy, i.e. the relative size of brain regions.

discussion: transparent topography?

MRI was in one sense absent from the brain constructed in the two studies described above: MRI made the studies described above possible because it could delineate CSF spaces and white matter lesions. But it did not really matter that MRI in particular was used in order to measure brain areas: previous research had done the same with other imaging technologies, such as computed tomography (CT). Wetterberg's group used MRI because the imaging technology they had access to happened to be an MRI scanner. What I mean is that MRI's role in this research work was only to make the body transparent so the eye of the observer could assess the size and content of brain structures. And this transparency of the skin and the skull meant that MRI technology also had to be transparent, so as to maintain a translucent void between the eye of the observer and the brain hence made intelligible by means of the eye and psychiatry's statistics only.

The tension between transparency (i.e. the erasure of technology) and technoscientific mediation is posited and quickly dismissed by anthropologist José van Dijck in her recent book *The Transparent Body*. She writes: "Imaging technologies claim to make the body transparent, yet their ubiquitous use renders the interior body more technologically complex. The more we see through various camera lenses, the more complicated the visual information becomes. [...] The mediated body is everything but transparent; it is precisely this complexity and stratification that makes it a contested cultural object."[33] My reading of van Dijck's book is that it is a critical cultural study aiming to systematically unmask transparency. In that sense, her theoretical premise is that transparency does not exist, because there is no such thing as a transparent representation or as an unmediated perception. In that perspective, which I share, all our representations and efforts to render the outside world intelligible are mediated by cultural frames of understanding—not least, scientific and technological ones. But the question is not whether transparency *exists* or not; rather, it is how the transparency utopia is created, conveyed, implemented. What van Dijck's analyses bypass is that the discourse of transparency dependent on the erasure of the technology that makes it possible coexists with discourses of technological mediation and layering. It is through that tension that the two poles of the dichotomy, transparency and mediation, acquire meaning—thus always in relation to each other. This is why I want to inquire about the implicit tension between *transparency* and *medium* in MRI—rather than dismiss the one side (transparency) of this cultural dichotomy.

The transparency performed with MRI in the research conducted by Wetterberg's group studied above had two main features. First, it was a two-dimensional gaze that was at work, using one "slice" of the brain as volumetrically representative of three-dimensional structures (i.e. the volumes of brain structures were approximated with their transverse area). The search for the normal brain demanded that these 2D-representations be comparable; those were therefore based on individual brain scans taken at a given anatomic height in the brain – on the level of the subject's basal ganglia (an anatomically defined part of the brain). The two-dimensionality of representation and measurement was acknowledged as an *approximation* made necessary by what were considered technical requirements: taking and using several scans of the same subject for the purpose of quantifying brain structures would take far too much time.

Second, the transparency was argued to be *objective*, as illustrated by Wahlund and co-workers' words in a publication: "In this way, an automatic, objective delineation of CSF and brain tissue was obtained."[34]

What Wahlund and co-workers referred to implicitly was a notion of objectivity attained through automation of the gaze; the kind of objectivity that historians Lorraine Daston and Peter Galison call *mechanical objectivity*. This mechanical objectivity usually refers to the automated, technologically mediated production of visual representations considered as true representations of reality. The truth-value of the automated, mechanical objectivity resides in its reproducibility, its lack of binding to the individual observer, which provides the cultural illusion of a direct, unmediated link with the reality it depicts.

Solveig Jülich has shown how early radiologists developed methods aiming to reach the early twentieth-century ideal of objectivity, stabilizing representations in order to fulfill the requirements of mechanical objectivity, which "paved the way for aperspectival communication between doctors."[35] Jülich makes clear that the objectivity ideal pursued in early radiology was based on two complementary elements: on the one hand, mechanical objectivity; and on the other, aperspectivalism, which Daston and Galison define as "the escape from any and all perspective", and an objectivity ideal "that eradicates all that is personal, idiosyncratic, perspectival".[36] Similarly, the visual rating scales developed for MRI and used to control observers' idiosyncrasies illustrate a striving for *aperspectival objectivity.*

These ideals of mechanical and aperspectival objectivity which underpinned the development of visual rating scales were, however, not totally reached. For instance, in the methods developed by Agartz, Wahlund and others, the automation of the gaze was not total. Some subjective (embodied, individual) features remained in their machinery of translating the flesh into objective images: Even the visual rating scale was still based on individual interpretations of the brain spaces; brain areas to be counted were drawn by hand on the computerized brain scan.

What is interesting to me is not that these methods were not perfectly objective according to given objectivity ideals. Rather, I want to emphasize that these remaining elements of subjectivity were not a problem *per se* as long as they could be disciplined within a predictable, inter-observer frame (such as the "visual rating scale"): Rather than augmenting objectivity, the purpose of this inter-observer frame was to make MR images compatible with existing measurements of the brain and psychiatry's clinical frame.[37] This points at something more fundamental: the objectivity striven for through automation of the gaze was a *requirement* for *transparency*, because the non-automatic elements of the technified gaze rendered human and technological intervention not so much subjective as *visible.*

Not only was the transparency enabled by MRI thought of as objective, as St. Göran's researchers wrote; but also, I would argue, the statement may be reversed: mechanical objectivity was transparent, and the objectivization/automation of the MRI gaze served the utopia of transparency.

MEASURING: TOWARDS A QUANTITATIVE NMR BRAIN

In parallel with the developments of methods of building a topography of the brain in which MRI was transparent, Wetterberg's group worked to develop an NMR topography of the brain, i.e. a way of organizing and characterizing brain space after measured NMR characteristics:

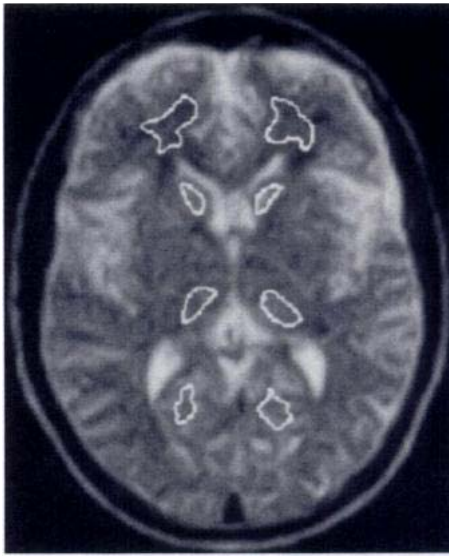


Figure 24. The small regions for which T1 and T2 were to be assessed ("regions of interest") were delineated on an MRI picture (4 areas on each side).[38]

Agartz: The aim was to be able not only to visually assess aspects of anatomical brain structures using a rating scale, but to objectively and automatically measure the size of different structures. To obtain information on the biochemistry of the tissues we measured the magnetic relaxation time constants. [---] The visual ratings were performed by the human eye, directly from the MR scans. But in order to automatically measure brain structures it was necessary to use a computer image analysis program [---] We acquired a system named GOP-300 which had been developed in Linköping. Using this program, we could automatically measure the size of areas of certain brain structures or tissue classes. We were also able to delineate discrete anatomical regions about which we had scientific hypotheses and were interested in, and measure the relaxation times. In this way, we obtained quantitative measures of tissue properties reflecting the biochemical differences [between tissues] – and that were quite characteristic of the different patient groups that we studied. [---] The valuable thing with the MR-technique is that it is non-invasive, with the opportunity to characterize tissue chemistry from a biopsy that has simply been obtained in the image of the living human brain, and not invasively, that is not through a surgical procedure.[39]

T1 and T2 were NMR parameters that were visible on many of the NMR images, since the intensity of each pixel was informed by (data "weighted with") T1 and T2 in different ways. But visuality was not always sufficient

Mean Values Plus or Minus Standard Deviations of T1 and T2 Estimates in White Matter, Caudate, and Thalamus in Healthy Subjects Aged 19–85 Years

Region	T1	*n*	T2	*n*
Frontal white matter				
Left side	200 ± 19	74	92 ± 19	68
Right side	198 ± 21	74	87 ± 18	68
Occipital white matter				
Left side	212 ± 17	48	96 ± 20	43
Right side	212 ± 20	48	95 ± 20	42
Caudate				
Left side	239 ± 18	70	100 ± 27	64
Right side	239 ± 18	70	99 ± 28	65
Thalamus				
Left side	225 ± 20	71	99 ± 26	66
Right side	224 ± 23	71	97 ± 21	66

Note.—*n* = number of subjects from whom estimates were obtained.

Figure 25. Typical results of the T1/T2 topography.[40]

to detect differences within brain tissue, for instance to detect lesions on an MRI scan, which fueled expectations of quantitative work with MRI ("using relaxation parameters as a tool in neuropsychiatric research, in which focal damage is not easily detected with a visual inspection of MR images").[41] In Lars-Olof Wahlund's words: "MRI gives a multi-dimensional information about tissues, [...] several parameters that could be combined in different ways and used to classify tissues".[42]

Could the physical/mathematical gaze be enhanced where picture contrast could not? Agartz, Wahlund and others at St. Göran's worked at mapping normal T1 and T2 values in different areas of healthy brains, the purpose of which was to establish a background for the (future) identification of brain diseases on the basis of T1 and T2 values.[43]

NMR characteristics did not replace the traditional anatomic grid as a way to organize the brain space; rather, the researchers superimposed NMR values on brain anatomy, creating what I call a quantitative NMR topography (or T1/T2 topography).[44] Figure 24 illustrates that the T1/T2 topographic grid did not cover the whole brain; rather, it focused on smaller local regions of the brain ("regions of interest"), defined manually on brain scans.

First of all, a spatial topography of T1 and T2 was found and quantified: the measured regions in the brain exhibited different mean values of T1 and T2. This topography was a "normal" topography: it was based on the NMR scans of healthy adults of virtually all ages; and the small regions of interest were "carefully outlined", taking "care [...] to exclude any alterations in the white matter, which had been noted to occur in some of the [healthy] subjects".[45] Hence, the regions of interest selected on brain scans were "supernormal". Paradoxically, the normalcy designed in that study was attempted to be representative of the population at large; results from volunteers who had somatic diseases were included as their NMR results were shown not to disturb the normal topography established on the scans of the healthy.

Isolated NMR images by themselves did not carry enough information to calculate quantitative estimates of T1 and T2. Images acquired a quantitative information value when combined with other NMR images of the same person-brain; Agartz and her coworkers used at least six different NMR images per person-brain. Therefore the set of six or more images was "geometrically matched" to each other with an algorithm. On one of the pictures, a small region of interest (like those shown in Figure 24) was manually drawn on a computer, and from the mean intensities in this region in the set of pictures, T1 and T2 were calculated.[46]

The result of this part of the study, i.e. the representational format of this T1/T2 topography against space, was here again tables rather than images. Figure 25 reproduces one such table: the main values of T1 and T2 produced by measurements of regions of interest are listed with their statistical variance across individuals for each brain area.

of pictures and data

The dichotomy picture/data seems to have mattered to many of the MRI actors, sometimes shaping their own ideas of what they were primarily doing with MRI; for example Agartz' explanations that her group longed to be able to conduct measurements in the brain rather than just look/see, or Sääf's words in the TV program *Knowledge of AIDS Research* about MRI's performing a million laboratory analyses in a picture set (cf. previous chapter). Similarly, Anne Beaulieu notes that although the practice of brain-mapping was to a large extent based on handling visual representations, the brain mappers working with PET distanced themselves from the pictorial understandings of their work, and rather defined their experiments as the handling of data. Her interpretation is that brain mappers/PET researchers wanted thereby to maintain their work's scientific status.[47]

However, Beaulieu argues that the data handled in brain-mapping and PET experiments was dependent on anatomy's pictorial tradition, both to "provide a spatial referent" for PET data, and to "convey the notion of control of the space of measurement". As a result, the object PET imagers work with is hybrid, shaped by both a pictorial/visual/optical tradition, and by a quantitative/digital one.[48]

Here I want to discuss what kinds of objects were manipulated in the MRI study of the brain's T1/T2 topography described above: Were they data or pictures? With which consequences?

Obviously, the purpose of the study was to acquire quantitative data from which T1 and T2 could be estimated. On the other hand, this acquisition was entirely bound to visual modes of representation: the delineation of regions of interest was done on images (nobody would have been able to define them mathematically within the corresponding set of data); T1 and T2 were approximated through processing of images, a process in which geometry was as essential as physics and mathematics in letting different data (represented and embodied in different pictures) acquire meaning in relation to each other and to the quantitative parameters to be estimated.[49]

Was the visual only a necessary or convenient way to work with complex data? No, NMR/MRI data were shaped by a spatial encoding of physical interactions (cf. Chapter 1), and by visual modes of representation that were conflated with fundamental principles of neurology and neuroanatomy. For instance, the way in which a region of interest was defined to estimate T1/T2 relied on assumptions about how different points in the brain relate to each other as structures. The idea that we have to consider brain cells as spatially coherent clusters functioning as entities in our mental processes is called localization. The very idea of localization was based on the emergence of neurology in the frame of modern anatomy and physiology; although not inherently *visual*, it is based on a topography of space attached to visual anatomic representations: the functional entities of the brain were solid shapes rather than, for example, distributed networks.

The relation between picture and data was thus not only one of form to content; rather, MRI representations were used both as visual-pictorial and mathematical-physical objects, although the dichotomy between picture and data was sometimes explicitly formulated (cf. Larissa Bilaniuk's talk at St. Göran's in the previous chapter). As pictures, these representations could pass as anatomical and be used as such; as data, they could pass as physical-mathematical and be used as such.

Thus, the process of *mapping* the representation of a phenomenon (here, T1 and T2 values) onto another representation (anatomic brain MRI picture), i.e. making the representation spaces match, is more complex than just superimposing one picture onto the other. In the process, both representation spaces are affected—and the new representation space is a layered, hybrid object. MRI pictures were much more than the representation or embodiment of data.

an NMR topography of brain space and lifetime

The T1/T2 topography of the normal brain did not correlate to any of the clinical and mental tests conducted on the healthy subjects present in the study. Nor did it correlate to the CSF-space topography. To map T1/T2 onto anatomic brain space may have been considered necessary, but it was not significant—it did not bring any new insight by itself.[50]

Nevertheless, age had previously been shown to influence T1 and T2 values. Wahlund, Agartz and their colleagues plotted T1 and T2 against the age of the participants for each small region of interest—and thus obtained a series of data and graphs, one of which is shown in figure 26. T1 was found to correlate with the age of the participants, i.e. Wahlund, Agartz and their colleagues found a statistical relationship between age and the values of T1 in the brain.[51]

The relationship thus established between T1 and age was "cradle-shaped," which the solid lines in Figure 26 demonstrated. T1 was found to decrease in the first decades of adult life; whereas somewhere around 40-50 it increased again towards values higher than found at young ages. (Why T1 could be dependent on age had only quite speculative interpretations.) [52]

More interesting than the results themselves, is that *time* came into the so far relatively static NMR topography of the brain. David Armstrong has argued that medicine's temporalization of the body through the establishment of norms of growing (for children) and ageing is to a large extent a twentieth-century phenomenon.[53] But which idea of time was embedded in this statistical model of T1 values in defined brain regions?

The *time* at stake here is the time of ageing. It is really an abstraction of time that was included in this statistical NMR topography of the brain: each healthy person participating in the study was made representative of their age. The study did not follow the participants in time; rather, it added lifetime as one of the axes/dimensions of the statistical space in which the NMR topography was inscribed.

The time embedded within the NMR topography was constructed as a "clean" time, an ideal time not blurred by the effects of disease or general degradation of the subjects' mental capacities. This was the result of selecting healthy study subjects; one of the studies even focused specifically on "successfully aged" people, i.e. people not affected by physical diseases or diminished intellectual capacity ("with above-average intellectual function"), in other words actively selected supernormal

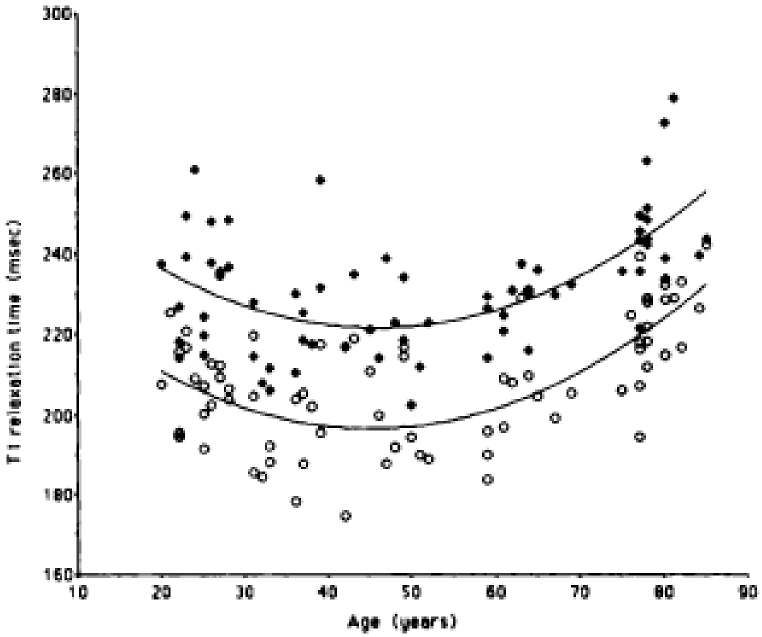


Figure 26. Mean T1 values of white matter (white dots) and gray matter (black dots) against age.[54]

individuals, more normal (healthy, non-pathological) than the normal (average).[55]

Thus, time was one of the dimensions of the social space to which the MRI gaze articulated individual bodies/brains (and therefore one of the lines along which research participants may be defined as supernormals). This specific integration of time as lifetime in the MRI gaze may then be understood as an integral part of what David Armstrong calls "a series of clinical shifts as medicine struggles to bring this moving object [the twentieth-century temporal body] under its clinical eye."[56]

CONCLUSION: PSYCHIATRIZING THE MRI GAZE

This chapter began by asking which MRI-based methods Wetterberg's group developed in their research work on the normal brain and why. I have been through two categories of methods. First, visual techniques: visual rating scales and automated (computerized) area measurement, which I have argued served the purpose of disciplining idiosyncrasies in the observers' judgment of the size of brain areas and lesions, i.e. establishing an aperspectival objectivity in distinguishing the normal from the pathological. Second, measurement techniques derived from the data collected with MR imaging and their associated NMR topography, which resulted from an explicit wish to detect invisible brain lesions, and which I have interpreted as the creation of a techno-clinical eye on the brain made temporal.

My second question addressed the technomedical production of the normal with MRI. Notions of the normal were built into the technological-visual apparatus that were, by and large, statistical (both in visual scales and in NMR topography). I have argued that the "normal brain" therefore worked as a system that re-situated individual brains (as research material) on a social grid. Although the normal MRI brain implied a statistical frame, it did not enable any probabilistic prediction of somebody's belonging to a given population group. Beaulieu's categories of normal brain atlases differentiated notions of the normal as characteristic, average and probabilistic.[57] The normal at stake in the MRI work under scrutiny here thus belonged to the notion of normal as average in homogeneous groups.

However, the issue of supernormalcy, not least in ageing, leads back to Daston and Galison's notion of the "ideal" depiction in which the anatomist/artist would draw not a specific, "real" example of object (body), but an imagined body freed from individual idiosyncrasies seen as imperfections.[58] I want to argue that the averaged brain produced in successfully aged/supernormals, although based on the processing of real brains, fell under the category of "ideal" brain when resituated in the majority context of "usual ageing". I have also suggested that as a result, the notion of time as lifetime embedded in the notion of normal brain (in the last research project I have studied) was itself ideal.

Here I want to reflect upon the way the MRI gaze operated in the settings of St. Göran's normal brain research. Just as in clinical use, the MRI gaze worked both as a transparent gaze producing and giving access to the brain "itself", i.e. brain anatomy, and as a visible, quantitative medium endowed with a normative space of its own and with the power to materialize concepts as abstract as an ideal ageing time.

In the previous chapter, I have expressed the view that a new kind of psychiatrists (and therefore, a new form of psychiatry) emerged in the 1970s whose purpose was to become like other medical disciplines—more somatic and more "scientific".[59] The examples I have analyzed in the present chapter suggest further that psychiatrists, at least at St. Göran's Hospital, also adopted methodological and scientific *ideals* from modern somatic medical science: aperspectivalism and mechanical objectivity achieved through technification. It may look as though it was MRI itself that brought scientific authority to St. Göran's psychiatric research (cf. Agartz' interview), but this chapter has shown that it was rather the *methods* developed for *using* MRI that were constitutive of ideals of science and objectivity.

Amit Prasad argues that MRI's contemporary visuality, like radiology's, requires that the body be made notational, i.e. dissociated in separable parts and made the bearer of non-visual, e.g. textual, information.[60] In other words, according to Prasad the flesh is transformed into a set of notations handled as the real body. The quantitative topographies analyzed in this chapter (the item lists with corresponding values on the visual rating scale, and the T1/T2 topography) are examples of such sets of radiological-anatomical notations. Using a similar interpretation of the MRI research on the normal brain, I want to argue that in the examples I have analyzed, brain anatomy was made notational by inscribing psychiatry's social and/or medical landmarks onto brain anatomy (in the morphometric studies analyzed in the first part of this chapter) or into the NMR topographies of the brain.

In other words, the MRI gaze further developed in St. Göran's research work was constituted by the integration of an anatomical MRI gaze into psychiatry's frame: by making the brain notational, statistical and socially situated in practice. Lennart Wetterberg presented the change brought in by MRI as a brain turn at St. Göran, i.e. an "anatomization" of psychiatry there (cf. Chapter 4). Returning that perspective, I want to argue that the MRI gazes that were implemented in St. Göran's psychiatry (among them, a radiology's anatomical MRI gaze), were "psychiatrized" in the process of developing their research use.

This chapter, together with the previous one, has explored the shaping of an MRI gaze in the context of a psychiatry department's clinical use and research work. Throughout the examples studied here, there have been reminders of the ambiguity of MRI representations and gaze as visual and/or quantitative, anatomical and/or laboratory-like. Whereas I will come back more definitely to this tension in the final discussion (Chapter 7), the following chapter (which is also the last empirical study in this dissertation) addresses more specifically the formation of a laboratory gaze in MRI's open-ended space of representations.

interlude

seeing beyond materiality? (an imaginary dialogue à trois)

EDWARD PURCELL: *Professor Bloch has told you how one can detect the precession of the magnetic nuclei in a drop of water. Commonplace as such experiments have become in our laboratories, I have not yet lost a feeling of wonder, and of delight, that this delicate motion should reside in all the ordinary things around us, revealing itself only to him who looks for it. I remember, in the winter of our first experiments, just seven years ago, looking on snow with new eyes. There the snow lay around my doorstep – great heaps of protons quietly precessing in the earth's magnetic field.* [1]

In 1952 physicist Edward Purcell received the Nobel Prize in Physics, together with Felix Bloch, for measurements of nuclear magnetism, which were one of the major steps in the development of NMR.

„IAN HACKING: The problem [of realism] arises because we have alternative systems of representation.[---] [Democritus' atomism] aims at a new kind of representation. Yet it still aims at likeness. This stone, I imagine a Democritus saying, is not as it looks to the eye. It is like this – and there he draws dots in the sand or in the tablet, itself thought as a void. These dots are in continuous and uniform motion, he says, and begins to tell a tale of particles that his descendants turn into odd shapes, springs, forces, fields [---].
The serious scepticism [...] originates with the more challenging worry that the hand represented as flesh and bone is false, while the hand represented as atoms and the void is more correct." [2]

Philosopher Ian Hacking confronted fundamental philosophical and historical debates about realism and relativism in *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (1983).

„BERTIL PERSSON: *The use of a [magnetic] field cycle opens for unexpected possibilities of studying the role of water within biology.... Because what is mostly explored in relaxation studies is how the water molecules are bound to macromolecules [such as proteins]. And there [the physical chemist] Bertil Halle has a theory of his own, or rather a hypothesis that he works with.* [---] *[He] has discovered that in each protein there is a configuration of a few water molecules, covalently bound in a crystal structure in the protein which acts as a resonator. And each molecule has its absolutely specific resonance properties. To me, that means in principle that it is possible to think that molecules can 'talk' to each other* [---].

The question that I have asked myself in these matters is: Where is the mind? It's something that I can feel—philosophically, physically, it must be somewhere. [---] *Professor Karl Trincher [...] wrote a book called "Natur und Geist" (Vienna 1981) that says: "Das lebende Wasser in den Gehirncellen ist die Stätte des Geistes", that is, that the mind rests in the water's structure in the brain cells. Altogether, this gives me an incredible incentive to try and research further within these frames—to try to map the biological consequences of Bertil Halle's discoveries; including how you can spin that off to a biological context and in the long run, visualize the mind..* [3]

Radiation physicist Bertil Persson conducted magnetic resonance projects on the brain's molecular interaction space in collaboration with physical chemist Bertil Halle in Lund in the 1990s and 2000s.

[6] cells, flows & relaxation times

shaping an MRI's laboratory gaze

During all these years in Lund we built up a very professional group, because we have always tried to develop the fundamental principle [of NMR/MRI] and an understanding of the mechanisms, not like in radiological diagnostics where you look at 'black and white'—and this has now enabled us to do really fantastic things with MRI.

My vision from the beginning was not just this "see in black and white" thing; instead I saw the deep dimension of NMR: the fact that we actually communicate with life itself. I usually explain MRI to medical students as that what we do is conduct radiocommunication with the body's tissues [...] and ultimately, with the body's molecules. We send a radio signal and ask "How is it in there?" and we get an answer back: "It's healthy here—or diseased." [1]

Radiation physicist Bertil Persson, from interview (2003).

introduction: a laboratory gaze

The words of Bertil Persson used as an introductory quotation for this chapter express Persson's vision of NMR imaging as a tissue characterizer, a cancer detector, a device that will inform about the living body's status and pathologies from cellular and molecular information obtained in interaction between the technology and the body's microscopic components.[2] The way of seeing or the *gaze* that he imagined for MRI was one of the laboratory—a gaze perceiving cells, molecules and physical interactions between matter and radiation.

Somewhat later during our interview, Persson formulated a more radical version of the history of MRI—that of this promising laboratory gaze that had landed (wrongly) in radiology's realm of crisp visual representations of anatomy:

> *Persson: …and that is what I have [always] said: the biggest disaster in the medical development of MR was that it landed in radiology. They have viewed MR rather blindly as an imaging technology […]. They have not seen what is behind the technology—and have neglected to develop that. Well, MR is much, much more than a picture in black and white.*
>
> *[---] [We have succeeded in Lund] in getting everybody to realize that this MR thing is so complicated, that you need close cooperation between clinicians and physicists to obtain the best results. This is how things are in Lund, but it is not at all like that everywhere. It is as if the doctors think that you just have to push the button to produce a picture, and then you read it and you know it all… It's not that simple at all—this is something much, much deeper.*[3]

In other words, not only did he envisage the MRI gaze as a laboratory gaze, Persson also fundamentally opposed this vision to that of radiology's—derogatorily referred to as "see[ing] in black and white", by which he indicated that, as he understood it, radiologists' way of looking into the body with MRI lacked a central dimension.

Persson's assessment of other actors' understanding of MRI is significant; but what is of most interest is that it is a *collective* feature that is the object of his criticism. As he expresses it later: "as radiology took over MR *in its discipline*, the exciting part of MR disappeared. [---] [I]t is the dictates of commercialism that determine [technological development], because if you want to sell, [you sell] what the client wants, of course. [*laughter*] What *radiology as a client* wants is nice black-and-white pictures." [4] This collective feature, radiology's way of seeing and handling the body, corresponds to what I have referred to as the radiological gaze throughout this dissertation.

The background that Persson outlines—that of radiologists making MRI "see" only in black and white—is reminiscent of sociologist Kelly Joyce's re-reading of MRI's early history, which I have introduced in the last section of Chapter 3. Joyce argues that the reasons why MRI became visual-radiological already in the early 1980s, were radiologists' increasing professional power in the USA, a visual turn in culture at large, and the fallen status of nuclear physics. Further, Joyce contends that radiologists' increased professional power in itself explains why MRI representations became images in black and white, a correlate of which was the disappearance of color-coded scans and quantitative MRI representations.[5]

However, I have shown in Chapter 3 that the ambiguity of MRI representations (as black-and-white pictures *and* quantitative data) endured in MRI researchers' shaping of a radiological MRI gaze. Persson's account of the achievements of Lund University is not only critical of the radiological gaze: He also suggests that radiologists' good practice was (or had to be) highly dependent on physicists' scientific understanding of how MRI worked and how it could be used. Similarly, physicist Freddy Ståhlberg who worked with Persson in the 1980s problematizes this image of a fundamental opposition of professional gaes and emphasizes the cooperation of radiologists in the shaping of flow and perfusion imaging with MRI—technologies that belonged almost exclusively to experimental laboratory practice in the 1980s.[6] The history of the development of NMR imaging as outlined by Stuart Blume (cf. Chapter 1), which Joyce criticizes, also suggests that the radiological gaze and the laboratory gaze were not fundamentally incompatible. From two main lines of development, which opposed proponents of NMR imaging as a cancer detector to supporters of NMR imaging as a radiological technology for whole-body imaging, a kind of hybrid had emerged, Blume argues: By the early 1980s, NMR was scaled up to whole-body imaging in the early UK and US research groups, and its most promising application was cancer identification.[7]

As a whole, it is thus impossible to tell that MRI's becoming radiological ruled out a quantitative MRI gaze. Here I shall rather investigate how MRI researchers realized the integration of radiology's anatomo-clinical gaze (visual, macroscopic imaging of static tissues based on separation principles studied in Chapter 3) and a laboratory gaze (microscopic and dominantly quantitative).

This chapter will explore Persson's group's early research in order to answer the following questions: How did his group shape an MRI laboratory gaze? In which relationship to these two sets of practices of the body, viz. the pathological laboratory's practices and radiology's anatomo-clinical gaze, was the MRI gaze constituted in Lund? [8]

My focus will therefore be on the experimental practice in the borderlands between quantitative laboratory science and imaging, and between physics and the body. This chapter has two main sections, which address two distinct lines of NMR/MRI research in what started as Persson's group in Lund: first, the focus on quantitative characterization of tissues and pathology with NMR/MRI; second, the local development of MRI techniques for flow measurement.

BEHIND IMAGES: WARRANTING THE VISUAL WITH LABORATORY SCIENCE

Persson had established contact with Mallard's group in Aberdeen during the summer of 1981 and together with three colleagues he engaged in building his own prototype NMR-imaging scanner in the basement of the radiation physics department at the University of Lund (cf. Chapter 2).[9] At the same time as he and his group worked on the building of their prototype NMR imager, Persson begun to lecture on NMR, attended conferences, and worked on a book which was rapidly published in 1982, entitled *Medicinska Tillämpningar av kärnspinnresonans—NMR* ("Medical applications of nuclear magnetic resonance—NMR").[10] Persson was active in establishing his role in the future of NMR in Sweden. For instance, in November 1982 radiation physicists in Lund arranged a two-day meeting under his direction for discussions entitled "Medical applications of NMR". The meeting was open to radiologists but dealt more with the physics and engineering of NMR than with radiology, and an explicit purpose of the meeting was to discuss the future role of radiation physics in the continued development of MRI.[11] The concluding remark of one of Persson's talks emphasized that "great hurry and interest have meant that the physical analysis had to stay in the background", and asked the question: "it is still hard to get much out of the existing devices—How is this to be done?" [12]

Persson's early exploration of NMR imaging was part of his efforts to build a prototype NMR scanner. The first device, which Persson's group had been working on since 1981/1982, was rather inexact and hardly produced pictures. The group started working on a new version, constructed more precisely, and in 1983 the machine was completed with a low-field magnet (0.07 tesla) and produced pictures—in Freddy Ståhlberg's words, "really bad pictures—but pictures!"[13] Persson and his group explained the principles of their device and used it in a new NMR workshop that they organized in Lund, mostly for Swedish radiation and hospital physicists, in June 1983.[14] They also presented their results in an international

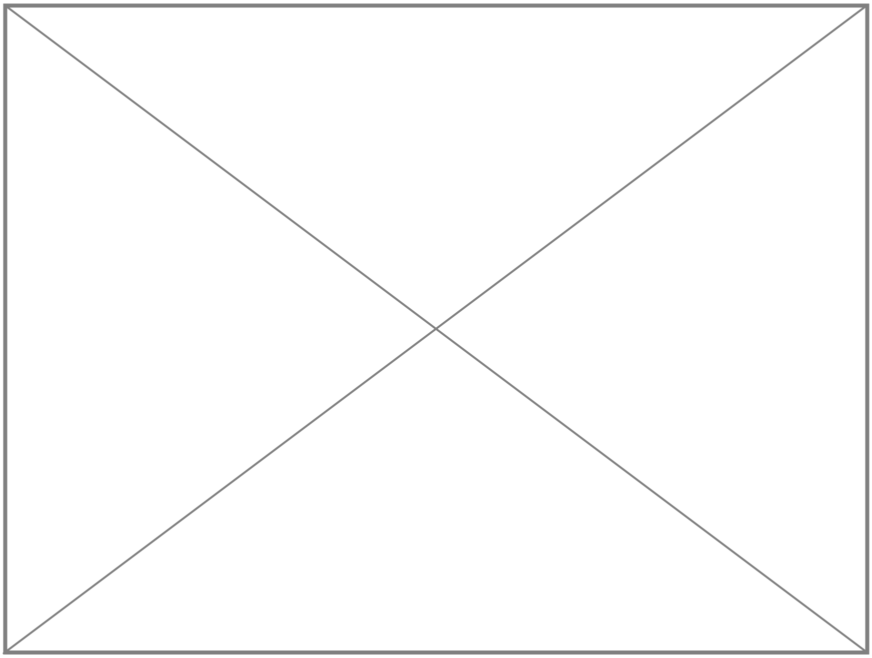


Figure 27. Bertil Persson's prototype of NMR scanner, Lund.
Photo: courtesy of Peter Lundberg.

symposium in Geneva in October 1983.[15] The device did not allow the study of big objects, but worked with samples.[16] However, Persson met difficulties in securing further funding of this development project and shifted direction, now focusing on academic research instead.[17]

In the early 1980s a medical doctoral student, Elisabet Englund, was working on brain-tissue characterization at the University of Lund's Department of neuropathology (i.e., pathology of the brain and central nervous system) together with pathologist Arne Brun. At the same time, Englund begun to work with Persson on the NMR characterization of brain tissue. M.D. Elna-Marie Larsson, who was conducting doctoral studies at the department of diagnostic radiology, also became involved in cooperation with Persson in the early eighties. Physicist Freddy Ståhlberg undertook Ph.D. studies on NMR imaging at the department for radiation physics, soon focusing on the effects of flow (such as blood flow) on the NMR signals and images and on the imaging of flow with MRI.[18] Bertil Persson, Freddy Ståhlberg, Elisabet Englund and Elna-Marie Larsson constituted in practice what I will refer to as the Lund MRI group.

In our interview, Persson outlines the main methods mobilized in his group's early work:

> *Persson: In that early phase when we were really pioneers, I had two medical Ph.D. students, one in radiology [Elna-Marie Larsson] and one in pathology [Elisabet Englund], who studied together the NMR relaxation properties of different tissues [...]. Among other things, we fetched fresh [pig] brains from the slaughterhouse every morning, and we looked at relaxation properties in different parts of the brain. After that you don't really want to eat pork—there wasn't a single healthy brain! What we did was a great deal of pioneering work on relaxation properties, and then on biopsy material and autopsy material (deceased patients) where we correlated the histopathology [the tissue changes that accompany a disease] with MR relaxation measurements.*[19]

Bertil Persson, Elisabet Englund and Elna-Marie Larsson, together with a few others (among them the pathologist Arne Brun and the radiologist Zoltan Györffy-Wagner) thus began to work on the differentiation of healthy tissues from sick tissues on a quantitative basis by *measuring* their NMR characteristics, the relaxation times T1 and T2. These NMR values were not only measured but compared with results obtained by established methods from the pathological laboratory. These methods involved the extraction of tissue samples from the dead body (autopsy) or the living body (biopsy) for further analysis with a battery of laboratory technologies (I will describe laboratory methods more thoroughly in the respective sections of this chapter).[20]

The choice of T1 and T2 as characteristics with which to explore bodily tissues was not random. I have described earlier (cf Chapter 1) the way that MR researchers understood the signals captured with MRI as bearers of two kinds of information: on the one hand, proton density, and on the other, the relaxation times T1 and T2. The earliest MR images (such as those produced by Paul Lauterbur in the 1970s) were basically maps of proton density. "The proton content," Persson argued in 1982,

> gives an information about density that is similar to the information about electron density given by X ray imaging. However, from a medical point of view, the relaxation times give a whole new kind of information. Using T1 and T2 or combinations of those, it is possible to conduct a kind of histological-chemical classification of the [human] tissues.[21]

Where proton density stood for traditional radiological information, T1 and T2 were in Persson's world the potential key to a new understanding and classification of the body (i.e. the "unique" possibilities that MRI afforded, cf. Chapter 3).

In a range of articles published in the course of their NMR work, Persson's group justified their early quantitative NMR characterization of bodily tissues by explaining that prior knowledge of which range of values T1 and

T2 took in the living body was necessary to the design and choice of "pulse sequences" for NMR imaging, i.e. for the technological choices embedded in the design of NMR images.[22] Whereas Persson's group's early exploration at first involved no imaging, the purpose of their attempts to characterize tissues with NMR was to provide a scientific background for the development of MR imaging, and to design the "pulse sequences" that would create the most appropriate *contrast* in MR images. As seen in Chapter 3, radiologists wanted to achieve contrasts that enabled them to discriminate between tissues and between pathologies. Persson's group thus wanted the quantitative NMR measurements to inform the MRI images, i.e. the visual NMR representations, and to warrant the scientific character of the visual.

In this section I scrutinize two specific studies that the Lund MRI group conducted within that quantitative laboratory frame. First, I consider their work in characterizing the *materials* (samples of brain matter obtained at autopsy or biopsy) used in their further experiments. Second, I focus on their central work on NMR characterization of tumors. These studies will enable me to answer the following questions: What did the Lund researchers enable NMR/MRI to see? How did they realize this shaping of the MRI gaze in practice?

bodily samples under scrutiny: calibrating the MRI gaze

The early Lund NMR studies of brain pathology were based on brains and brain samples obtained at autopsy, i.e. after the death of the patient, or at biopsy, i.e. where samples of the brain were removed from the patient's living brain tissue e.g. with a needle or by surgical intervention. But did the samples and dead brains have the same NMR characteristics as the living brain? After a first series of experiments that mapped the NMR values of the healthy brain in pigs and humans, the Lund MRI group conducted studies intended to assess the effects of the use of samples on what I call the NMR body, i.e. the body as described and constituted with NMR.

Media scholar Lisa Cartwright writes that microscopists used (and use) a range of techniques to adapt the body to the apparatus of the microscopic gaze. She writes: "Even in contemporary microscopy, observers go to great lengths to manage depth, "cleaning up" and "correcting" unwanted levels of action in the microscopic frame." "Cleaning up" refers here to microscopists' selection and construction of study objects, for example with the erasure of unwanted aspects (such as bodily presence, the spectacle of pain in laboratory animals or spatial depth in the bodies studied).[23] Similarly, the Lund researchers' production of representations

NMR and MRI implied a range of interventions in the bodily materials under study in order to make these usable. I consider the Lund MRI group's analysis of the effects of sampling the body as a series of "cleaning ups" of NMR representations and hence, of the NMR body.

A first series of experiments addressed the relation between death and the NMR samples. If reliable footprints of pathology (such as T1/T2 values of tumors), i.e. knowledge of the living body, had to be produced on the basis of dead brains and samples physiologically dead, then the effects of death on NMR values had to be characterized and corrected for, as Györffy-Wagner and his colleagues wrote:

> Such determinations [in vitro determinations of T1 and T2] are also valuable in attempts to discriminate between different pathologic changes by means of T1 and T2 values. The validity of those values in tissue samples is therefore of particular importance. *The relaxation times could be influenced by different factors, among which are the time delay after excision or death and the temperature under which the samples have been preserved.* Knowledge of the effect of these factors is necessary when in vivo measurements made on patients before operations are correlated with measurements performed on surgical or autopsy specimens.[24]

This was done in a couple of early studies in Lund, conducted on pigs and humans respectively.[25] Extensive and technology-intensive experiments were required in order to learn about the impact of death on the NMR body. To give a concrete impression of the battery of techniques mobilized in such work, I quote below an excerpt from the methods section of a publication on the pig brain experiments:

> The animals [pigs] were [...] killed by inhalation of carbon dioxide and exsanguination. The brains were removed immediately after death and within two hours frontal cortex, frontal white matter and the caudate nucleus were dissected. [...] Thus, a total of 81 samples were available for measurements. A small piece (about 25 mg) was taken from every sample for water content determination before the first MR measurement. The small pieces [...] were put on glass slides, weighed and dried at +65ºC [...] for a minimum of 24 hours. They were thereafter weighed again and the water content was calculated. The tissue volume for MR analysis was 1 or 3 to 5 ml in closed glass test tubes with a diameter of 1 or 2.5 cm, respectively. [...] The samples were incubated at +37ºC for 15 to 30 min before being measured in a Praxis II pulsed MR analyzer. The measurements were performed at +37ºC for protons at 0.25 T (10.7 MHz) with the pulse sequences (90º-τ-90º) and (90º-τ-180º-τ) for T1 and T2, respectively. The MR signals were measured on line and stored in an Apple II computer. [---] [S]ignal registrations were made in 30 points, each representing an average of 4 to 5 signals.

> The samples were analyzed 4 to 6 times during the time interval 2 to 90 hours postmortem. Between the measurements they were stored in a refrigerator (+8ºC). [...] In all 322 measurements were performed on the 81 samples.[26]

As this quotation illustrates, such extensive measurements of samples did not follow a hypothetical natural process of death and the probable decay, dehydration etc engendered by time after death. Rather, the Lund researchers re-created in the laboratory the conditions of technified postmortem time (postmortem meaning after death) as used in medical research: for example, the samples were kept at the same refrigerator temperature as corpses preserved for autopsy usually were. Finally, the T1 and T2 values of the samples were repeatedly measured in an NMR device, within the time interval that corresponded to standard postmortem experiments (2 to 90 hours after death – up to 120 hours in humans). For that purpose, the samples were warmed for measurement and refrigerated again between experiments. The series of T1 and T2 values obtained were then analyzed: Did they perceptibly change in the postmortem interval?

Whereas certain aspects of the technified dead time (postmortem time), such as the repeated warming and cooling of samples between NMR measurements, were established as transparent (they did not affect the NMR values of the samples), postmortem time itself was found to induce a slight decrease in the tissues' T2 value. On the basis of this study, the Lund group recommended that the influence of dead time on NMR values of brains and brain samples (as preserved and treated according to the usual autopsy/biopsy practice) be ignored. If the NMR body was not to need cleaning from the influence of death, at least death could be cleaned from the suspicion of inducing major distortions in the NMR body.

A second series of experiments addressed the relation of samples to the living body. All quantitative NMR measurements that the Lund MRI group conducted to characterize normal and pathological brain tissues were performed *in vitro*. This means that instead of measuring directly within the living body (which quantitative NMR could not do), small samples were extracted from the brain, isolated from the living body, rendered compliant to the technological devices used for analysis (by being dried or dissolved, put on a glass slide or in a tube, tainted, etc.), and analyzed. In contrast, MRI provided *in vivo* information (i.e., information produced within the living body) but did not allow *measurements* of the relaxation times T1 and T2; at best, T1 and T2 could be approximated ("estimated") from sets of MRI images (cf. Chapter 5).

An early issue for the Lund researchers was to establish whether the knowledge established on the basis of such *in vitro* measurements and analyses was compatible with the higher purpose of those, *in vivo* imaging with MRI. An explicit concern was about the absence of blood flow in the samples: "A disadvantage of in vitro measurements is the absence of blood flow in the tissue examined, which is different from the in vivo situation," Larsson and her colleagues wrote.[27]

Among other things, blood flow was known to influence MRI signal *in vivo* by causing a decrease of the signal observed on the images. Moreover, tissues comprised blood vessels—with blood *in vivo*, and without *in vitro*. How should the NMR values of bloodless samples be interpreted then? The Lund group's results were similar to those of other researchers who had found "only slight differences between relaxation times in vivo and just after death" (approximated with MRI or measured with NMR) when blood had ceased flowing.[28]

Not only were NMR measurements of samples considered close enough to these *in vivo* MRI characteristics; the researchers even argued that the measurements with NMR were more accurate working objects than the living body and MRI images: When MRI scans were used to approximate NMR values of tissues (T1 and T2), small regions of the image were selected for averaging—but it could be difficult to visually isolate gray matter from white matter, and the selected regions could contain unwanted components (white matter, blood etc) in addition to gray matter. In contrast, the *in vitro* NMR studies had the advantage of getting NMR values of purer samples than MRI.[29] In other words, the quantitative NMR results obtained *in vitro* were characteristic of pure, unmixed, clearly separated tissues: the components of the ideal anatomical body.

Similarly, in *in vivo* MRI imaging, the physiological movements occurring in the body (such as blood flow or respiration) were considered as a noise, a "degradation" of the "true" MRI picture, as radiologist Elna-Marie Larsson (among others) described:

> MR is vulnerable to image degradation from various types of patient motion that occur during the [...] acquisition time of the pulse sequence [...]. Physiological motion, especially that related to cardiac activity, respiration and peristalsis of the alimentary tract, gives rise to artifacts on MR images of the chest and abdomen. The absence of these types of physiological motion is an advantage in brain and spine imaging, although thoracic spine images may be affected by artifacts caused by the cardiac activity. The oscillatory pulsation of the cerebrospinal fluid (CSF) may, however, degrade the spine image quality [...].[30]

To save the "vulnerable" anatomical MRI body from the disturbances induced by bodily life, "[s]everal techniques for the reduction of motion-induced artifacts have been applied with varying degrees of success" in the 1980s.[31] The *in vivo* MRI body was also "cleaned up" as much as possible from the disturbances of life processes—retaining from the flesh a good enough approximation of the anatomical body.

Was it so surprising that the reference body in Lund's laboratory studies was the anatomical body? Historically, the anatomical body has been the product of a medical knowledge based on the study of corpses by dissection from the 16th century onwards. As Catherine Waldby argues: "The corpse, rather than the living body, is central to the production of anatomical working objects, and hence to anatomical knowledge more generally. Anatomy, which produces visual texts about the living body's organization, does so through the analysis of dead bodies [---]."[32] Thus, the anatomical body was in many ways a dead body. If the object of the Lund NMR studies was the anatomical body, then it was not fundamentally relevant what life processes and *in vivo* situations looked like in the NMR space, as long as they were not perturbing the characterization of tissues and their pathologies.

However, there was something more paradoxical with MRI: Whereas the ultimate purpose of MRI research was to create knowledge of the body and life processes, including the pathological, a central focus in the 1980s NMR/MRI research such as that analyzed here was the characterization of the NMR/MRI technology itself. I have shown that one reason for researchers' interest in technology itself is that unwanted objects and processes such as blood, blood flow, death, motion artifacts influenced NMR/MRI values. Therefore, as NMR/MRI were used and further designed to track the footprints in the body of normal and pathological processes, they also potentially captured the unwanted marks of many other processes. These "other processes", of which the most threatening to the exactitude of measurement were processes of bodily death and physiological life processes (motion), were considered to corrupt the "true" NMR information about the pathological. This section has explored how the body was "cleaned up" from these "corrupting" factors (or from the idea of them) and thereby had NMR to extract only the anatomic body from the flesh.

I have thus made two points in this section: First, the NMR/MRI gaze was "calibrated" on existing procedures of management of the body embedded in the laboratory's fundamental methods: sampling at biopsy and autopsy. Second, anatomy was thereby integrated as a frame in the laboratory methods of the MRI gaze; and I read this process as an alignment of the MRI gaze on an ideal anatomical body.

tumor quantification: making NMR/MRI part of the laboratory gaze

Amongst all pathologies, the Lund MRI group focused on brain tumors and dementia for their quantitative work.[33] This was not unique; rather, visualizing and characterizing brain pathology and especially tumors was a dominant endeavor in the early years of MRI. The existing imaging technologies, dominated by X ray computed tomography (CT), enabled the diagnosis of many kinds of tumors on the basis of their shape and location; but to differentiate between tumors was not always easy, neither was it easy to identify their grade of malignancy. The researchers hoped that NMR would overcome the shortcomings of existing radiological-anatomical technologies in the detection and characterization of tumors.[34]

The Lund MRI group used NMR to characterize different types of tumors and different grades of malignancy—a set of projects which I will refer to as "the tumor study".[35] In the tumor study, samples from brain tumors from a large number of patients were taken by biopsy or during neurosurgery. The researchers first transformed the samples according to standard procedures to make them fit for the battery of NMR and laboratory tests.[36] The samples were inserted in an NMR analyzer, submitted to NMR excitation and measurements which produced their T_1 and T_2 values; they were also submitted to a range of histopathological laboratory tests, based on the microscopic analysis of pathological changes in bodily tissues.[37]

The pathologists of the tumor study submitted the samples to the standard pathological laboratory procedures of determination of water content in order to extract information about the composition of the tissues. They produced and analyzed microscope images of the tissue samples, with regards to (among others) the tissue's vascularity (number and size of vessels), size and organization of cells, and absence or degree of necrosis (by and large, dead tissue). With these methods the pathologists quantified classical pathological traits like necrosis and fibrosis of tumor tissue as percentages, identified respective kinds of tumors, and attributed tumors a grade of malignancy.[38]

The analysis of microscope images enabled the pathologists to make a classification of samples. Figure 28 is an example of the microscope pictures which showed the cellular arrangement of four different tissue samples analyzed by the Lund MRI group. The pathologists identified the top left picture's disposition of cells as "normal white matter". In contrast, they saw in the top right picture (b) a "moderate increase in cell size" taken as characteristic of a "low grade astrocytoma". The bottom left picture (c)

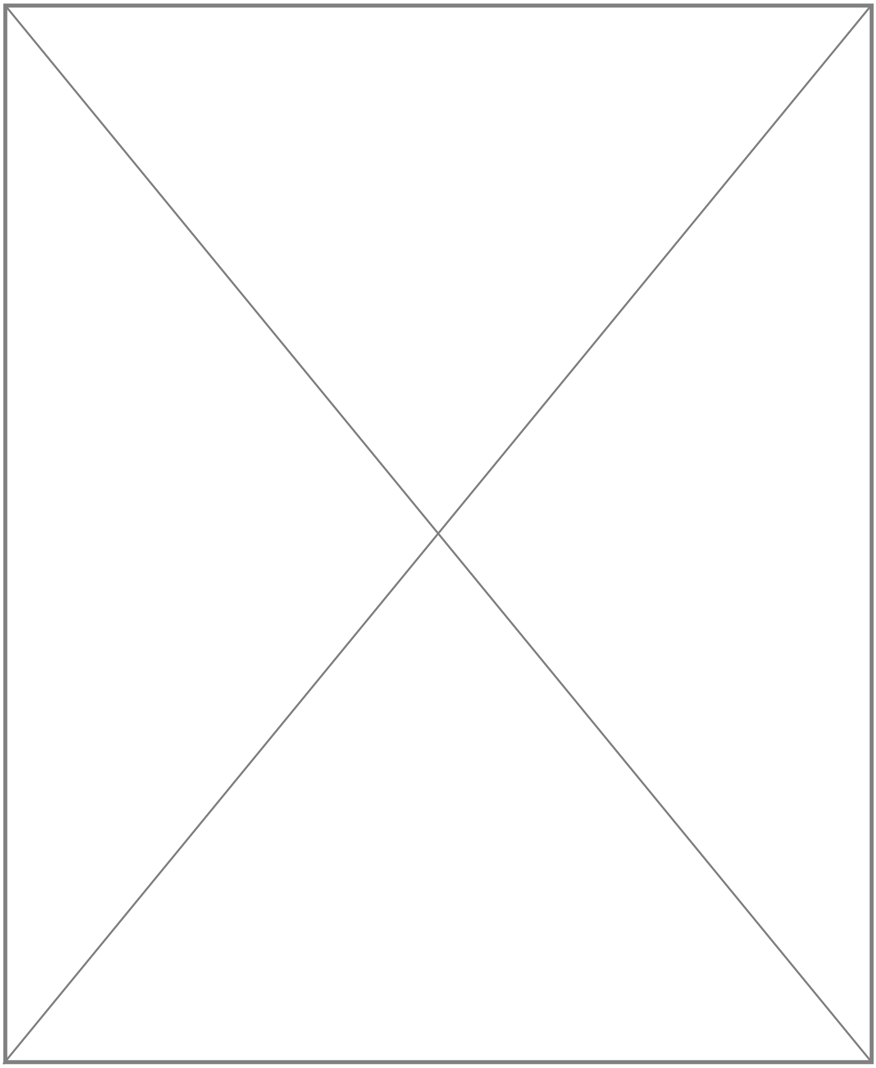


Figure 28. Microscope pictures for cross-referencing of NMR in the tumor study. The images show (in a microscope's way) the cellular arrangement of four tissue samples. These samples present different categories of pathologies: from healthy (top left) to three different forms of cancer.[39]

showed both a darker zone (on the upper part of the picture) with a high density of cells with irregular forms (which the pathologists characterized as "highly malignant astrocytoma") and a clearer area below identified as necrosis. In the bottom right picture (d) the pathologists saw a uniformly dense tissue with new vessels, on the basis of which they categorized the sample as part of an "oligodendroglioma".[40]

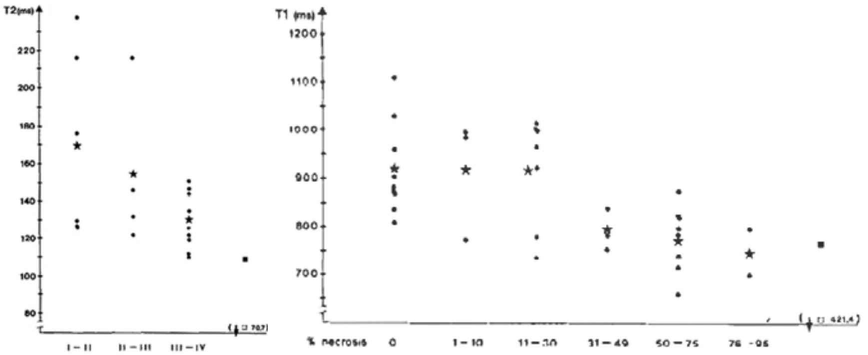


Figure 29. Graphs of results for one group of tumors ("astrocytic gliomas"). Left: Plot of T2 (vertical axe) against malignancy grades (horizontal axe). Right: Plot of T1 (vertical) against necrosis rate (horizontal).Each dot represents a sample, characterized by one histopathological feature and one NMR value.[41]

The result of the set of procedures described above was that the Lund researchers "thus had an exact histological documentation of tumour tissue and corresponding proton relaxation times of each sample," which were presented in tables usually giving mean NMR values and variance for each tumor category.[42] Figure 29 shows an example of yet another method by which the Lund MRI group made sense of the histopathological and NMR results: graphs. In a first series of graphs (not reproduced here) the Lund researchers plotted each sample, as well as "boxes" delimiting the range of T1 and T2 values observed in normal tissues, on a space that had T1 and T2 as axes. On that NMR map it became evident that many of the tumor samples were outside the quantitative domain of the normal.[43] The researchers then constructed the graphs reproduced here as Figure 29, by plotting a sample's T2 value against the malignancy grade they had labeled the sample with at histopathological examination (left graph; the same was done with T1 against necrosis on the right graph; and with other combinations of NMR and tumor data on graphs not shown here).[44]

The graphs obtained by plotting samples in the mathematical spaces of NMR/tumor characteristics suggested a relation between malignancy grade and NMR characteristics: for instance, Figure 29 suggests that the range of NMR values seemed different for different malignancy grades and extents of necrosis.[45] Some of these relations, such as the significantly higher T2 values of low malignancy astrocytomas, were established with statistical analysis. Within the tumor group of astrocytic gliomas, the Lund researchers established that T1 and T2 values decreased with the increase of necrosis.

They also established that different tumor groups exhibited different sets of T1 and T2 values, and thus that NMR could be a complementary method in the identification of tumors. To put it shortly, in the tumor study, the Lund researchers established NMR differences between kinds of tumors and between grades and necrosis states: NMR values made sense within histopathology's frame.

Here I want to reflect on *how* the Lund researchers constituted an NMR gaze in the tumor study. NMR could characterize some of histopathology's categories with its own quantitative representation space based on T1 and T2—but it was submitted to histopathology's classifications. What was the system of practice that made T1 and T2 the bearers of characteristic information about tumors, i.e. that made them intelligible within the frame of pathologist's tools?

Historians of science Solveig Jülich and Bernike Pasveer have analyzed the efforts of early radiologists to interpret X ray images, and listed radiologists' four comparative strategies: comparison of scans of known objects with the object; of scans of the body with established anatomic depictions; with clinical methods; and with other X ray scans. In contrast, it is impossible here to list a definite number of comparison strategies in the NMR tumor study. There the researchers mobilized an arsenal of technologies that each produced their partial representation of the sample. Rather than a one-by-one direct comparison of T1 and T2 values with a microscope image, a water content measurement or a percentage of necrosis, it is the researchers' combinations of these established partial facts that constituted the frame of comparison for the NMR results.

Sociologist Amit Prasad introduces the notion of cross-referential network in his study of the contemporary diagnostic (radiological, clinical) use of MRI, which is also valuable in making sense of the experiments conducted in Lund's early tumor study. Prasad's premise is that MRI scans are configurations of the body with unstable, i.e. *a priori* undefined, meanings. He explains that it is through systematic comparisons with other representations or facts produced with other clinical methods that radiologists are able to interpret MRI scans and formulate unequivocal diagnoses. The cross-referential network is the assemblage of the resources mobilized by radiologists to achieve closure on pathology; and it frames the diagnostic process of cross-comparison.[46]

In the tumor study, histopathological tests of the samples and their cross-referencing with NMR mobilized a heterogenous complex of quantitative and visual representations, aiming at establishing relationships between them. The core of the cross-referential network was constituted by the techniques of the pathological laboratory and the available histological classifications of tumors, which framed the researchers' design of the NMR experiments and the meanings of their results.

My reading of the tumor study is that the researchers stabilized the open-ended meanings of NMR representations with the cross-referential network of the pathological laboratory. The NMR gaze constituted as a result of this process was disciplined within the frame of that network and made the bearer of the pathological laboratory's practices (and understandings) of the body.

Was the laboratory's cross-referential network enough to wholly discipline the meaning of NMR values? Not entirely. First, the instability of meaning of NMR results was illustrated by the difficulty of comparing Lund's results with those obtained by other groups on similar tumor types. As the elements of comparison forming the cross-referential networks differed between studies (for example, studies prior to the Lund NMR tumor study did not often include histological data), the intelligibilities created within the networks were incommensurable.[47]

Second, to discriminate between tumors on the basis of T1 and T2 proved to be difficult, with the exception of certain kinds of tumors with characteristically high NMR values.[48] To quote but one such conclusion from a publication: "Because of the partly overlapping values, relaxation times alone cannot determine the type of tumour".[49] In the quantitative NMR search for tumor definitions and malignancy types, the same kind of overlap problems would be encountered as with trying to read out the tumor from the healthy tissue or to definitely identify the type of tumor on a CT or MRI scan. For many tumor types, the range of quantitative NMR characteristics of cancerous and healthy brain tissue overlapped too much to be systematically, i.e. predictively and unequivocally, separated.[50] Although NMR's quantitative methods effectively informed and to a certain extent improved the radiological identification of tumors, the problems that MRI users met in the space of quantitative logic proved to be aligned with that of the visual logic.

Thus, the Lund researchers' attempts in the tumor studies were successful in the sense that they confirmed that different pathologies in general exhibited different NMR values; but the lack of predictive or absolute categorization power of these results limited the horizon of applications of tissue characterization with NMR/MRI. It was mostly in informing diagnosis together with other clinical signs and data, i.e. when it was part of cross-referential networks aiming at zeroing in on pathology in individual patients, that tissue characterization with T1 and T2 could possibly play a role.

Prasad argues that the ambiguity of MRI scans caused by their visual character explains the difficulty of detecting or identifying pathology in single MRI scans.[51] In contrast, I argue that this persistent ambiguity of MRI representations was also true of NMR data, which points at a resistance phenomenon which is not rooted in the visuality of the radiological gaze. In her study of microscopy in *Screening the Body*, Lisa Cartwright introduces a reversal of agency in the microscopic apparatus. Her first analyses show a configuration of power in which the microscope observer or researcher as a subject endowed with agency looked upon and disciplined its object (things placed under the microscope's lenses), and for that purpose corrected it to suit the observation apparatus. She then moves on and shows how the microscope's apparatus subjected the observer to "corrective techniques". As a third move, she studies "the unruly objects of the microscopic gaze", referring to the failure of objects to conform to the microscopic gaze and to "the real anxiety experienced by the observers [...] over the agency and autonomy of their objects of study." [52] In line with Cartwright's somehow provocative approach, I want to argue that the difficulty of simply categorizing tumor types and grades with the two parameters T1 and T2 may be read as a similar anxiety-generating tension: the flesh did not comply with the gaze used by the researchers to make it intelligible.

Which were the aspects of that gaze that met with resistance? What we can see in the tumor study is that as part of the clinical gaze and apparatus, the NMR gaze organized and performed a relation between the individual body (literally, the flesh) and the de-individualized, quantified disease. Guided by histopathology, the researchers made the NMR gaze translate the individual flesh (although in a sample form, "stripped of its corporeality, its function and its history" in Cartwright's words) into clinical disease categories: tumor types.[53] The failure of the NMR gaze to positively identify and categorize tumors may therefore be read as the failure of the laboratory to get the body to conform to the categorization processes of the clinical gaze and to the power of that gaze to de-individualize the flesh.

In this section, I have made the point that the Lund MRI group made sense of NMR values by stabilizing them within the cross-referential network of the laboratory. I have shown that the Lund researchers thereby realized an integration in practice of the laboratory gaze in the NMR/MRI gaze. I have also shown that NMR/MRI's laboratory gaze met resistance from the flesh, and that the diagnostic ambiguity of MRI representations was therefore not specific to the visuality of MRI scans.

conclusion: the pathological laboratory's sharpening of the radiological gaze

In this first part of the chapter I have made three main points, which I recapitulate here: First, the Lund MRI group conducted quantitative NMR work within the methodological frame of laboratory work. Persson's work was grounded in the vision that MRI/NMR was a quantitative, molecular technology. However, the work of Persson's group often had its points of departure in radiological issues (e.g. the poor radiological differentiation of tumors). The Lund NMR/MRI group's ambition was also to enhance the scientific basis of the radiological practice and development of MRI.

Second, the Lund researchers' scrutinized the NMR apparatus itself, which included the materials it used: samples. They conducted a series of "cleaning ups" of layers in NMR's process of representation (measurement) of the body. As a result, the NMR gaze was calibrated on an ideal anatomy, and the NMR body (the working object of the gaze) was a purified, or ideal, anatomical body.

Third, the Lund researchers made sense of quantitative NMR/MRI representations (T_1 and T_2 values) through the cross-referential network of the pathological laboratory. Within that frame, they could establish correlations between NMR values and tumor categories, enhancing contrast-making and differentiation between tumors. Hence the Lund MRI group had NMR to *sharpen* the tools of the visual radiological gaze by quantitative means.

However, the Lund researchers could not entirely stabilize the NMR gaze as the individual variations between tumors/brains did not wholly conform to mediated categorization, and as variations between different local cross-referential networks did not allow researchers to unequivocally define fixed, decontextualized NMR values of pathologies.

I also want to add that even when the flesh complied with the laboratory gaze, the laboratory's cross-referential network did not simply determine what NMR/MRI representations meant. In another study which I have not analyzed here, Englund, Brun and Persson succeeded in characterizing a histologically contested pathology, "incomplete white matter infarcts" with NMR values.[54] This shows that NMR/MRI was soon used to reinforce histopathological facts; i.e. NMR/MRI representations were themselves made part of the pathological laboratory's cross-referential network. In other words, NMR representations were cross-integrated in the laboratory apparatus rather than simply disciplined through it.

FLUIDS, PHANTOMS & ARTIFACTS: FLOW IMAGING WITH MRI

If Persson described the stream of research I have analyzed in the previous sections as opposed—or rather, necessary—to the radiological gaze, he and Freddy Ståhlberg pursued a second line of exploration that seems even further away from anatomy: the imaging of bodily flows with MRI. In his book on the medical applications of NMR imaging, published in 1982, Persson expressed his vision of how invaluable a clinical contribution combined NMR measurements of blood flow and NMR imaging would afford:

> A combination of NMR tomography with non-invasive measurement of blood flow with NMR technology will be a powerful clinical tool. [---] [The method] may be developed into a general screening method for heart and circulatory diseases. Such an instrument would be able to generate pictures of the blood flow in different cross-sections of the body. Through a color display system, the blood flow in arteries and in veins could be displayed in red and blue scales, respectively, whose intensity is proportional to the flow. This information coupled to tomographic images of proton density, relaxation time etc. will become an extraordinarily valuable tool in medical diagnosis.[55]

Persson seemed even more enthusiastic about the technical prowess of future NMR images than about their potential clinical use: flow and NMR measurements of bodily tissues would be mapped in color in a holistic display.

In the first part of this chapter, I have shown how the Lund group shaped an MRI's laboratory gaze by endowing NMR with powers of seeing what the methods of the pathological laboratory "saw". An advantage (and a prerequisite) was the obliteration of the disturbances of bodily motions such as blood flow. Here I want to analyze how Lund researchers created an MRI gaze that aligned with a physiological body and visualized flows.[56]

I shall first outline how Freddy Ståhlberg and a few other Scandinavian researchers came to engage with flows. Then, in contrast with my previous approach, I will only outline the technical construction of representations and focus on the use of a test object (phantom) for what Lisa Cartwright has called the "management of living matter".[57]

going (international) with the flow

In the 1950s wave of NMR studies, flow in liquids was early observed to influence NMR measurements.[58] Experiments were conducted that attempted to use NMR as a way to measure flow, in vitro and in vivo; the first measurement of blood flow in vivo was realized by Singer in 1959. An NMR coil was wrapped around e.g. the arm and NMR was made to "encode" flow, i.e. to make flowing blood a bearer of NMR information. That technique could give quantitative measurements focused on one point of a vessel. Such NMR flow measurement was tested in different patient groups, but was not recognized as a clinical technology.

As NMR imaging was explored in the late 1970s/early 1980s, flow in the living tissues was formulated, on the one hand, as a problem, since it perturbed the NMR signals and therefore the NMR image of the inanimate tissues around the flow areas.[59] On the other hand, NMR images of flow also became an object of inquiry in their own right.[60] A few US scientists published results of NMR flow imaging in the early 1980s, and optimistic prognoses were presented in international NMR conferences, as NMR researcher C. Tyler Burt wrote in 1982:

> Indeed one of the more impressive demonstrations of flow was shown by Technicare at the Chicago 1981 RSNA meetings with a gated NMRI study of a human patient where the aorta darkened or lightened depending on where in the cycle the image was taken. The change correlated well with the expected phases of blood flow.[61]

It seems that it was MRI that first popularized NMR methods for flow measurement in the clinical world of the early 1980s.[62] The hybridization of NMR flow measurements and NMR imaging was however first envisaged as a qualitative flow-imaging method rather than a visualization of quantitative information—probably because the latter was technically hardly thinkable. In C. Tyler Burt's words: "The difference between NMRI [NMR imaging] and flow studies is that NMRI thus far is an interpretive technique whereas flow measurements have been developed as quantitative ones".[63]

In Lund, Persson had received a research grant from the Swedish Medical Research Council for experimental studies of flow, among other means with NMR (cf. Chapter 2). Freddy Ståhlberg began his exploration of MR imaging with research on MRI-based flow measurements. The field was in its infancy, but the first preliminary observations had become public and Ståhlberg had heard about them: "That was really interesting," he says in our interview, "there had been several articles from the USA saying that it was possible to measure flow [with MRI]."[64] Early research reports bear witness to Ståhlberg and Persson's interest in NMR imaging of flows.[65] Ståhlberg attended several international NMR conferences in 1984 where he made contact with NMR researchers working on the development of methods for flow visualization. He reported on the main methods used to image flow with NMR and commented that the field was still open for more developments, since "clinical studies, in which quantitative flow data have been correlated to a special disease or diagnosis are still few and [...] much work remains to be done".[66]

Ståhlberg explored MR flows, first on Lund's "homemade" MR scanner and later on Uppsala's MR device together with physicist Bo Nordell.[67] Nordell recalls in our interview that he was a Ph.D. student in radiation treatment in Stockholm when he took a course led by Bertil Persson—according to him, the first course on MRI in Sweden.[68] There he came into contact with Freddy Ståhlberg. When Uppsala were about to get their MRI device, in 1984, Nordell and Ståhlberg together presented a poster about flow NMR at the Swedish annual medical meeting *Läkaresällskapets Riksstämma*. In our interview, Nordell tells me that he and Ståhlberg envisaged contacting the MRI team in Uppsala to tell them that the two of them wanted to work on Uppsala's MRI scanner. Still according to Nordell, there was one project that Uppsala's MRI group did not have in their evaluation of the technology—it was the studies of *flow*—and Ståhlberg proposed that he and Nordell would be working with MRI flow studies. Their application to use Uppsala's device and thus participate in the national MRI-evaluation project was accepted and soon Nordell and Ståhlberg were part of the early efforts to quantify and visualize bodily flows with MRI.[69]

Soon a research network emerged between MR researchers from Stockholm (Nordell), Copenhagen (Olle Henriksen), Uppsala (Bo Jung, Anders Ericsson) and Lund (Ståhlberg) which explored flow MRI.[70] In our interview in 2003, Freddy Ståhlberg explained how that network started and evolved, limited on Lund's side by the MRI hardware available at Lund University Hospital's Department of radiology:

> *Freddy Ståhlberg: [...] It meant that the research that I was conducting just then—which was my speciality, flow measurements—I wasn't doing it in Lund on the* F*ONAR* *device. In other words, that defines two lines: The first line in physics-related research [---] dealt with flow measurements and was conducted first in Uppsala in 1984, then in Uppsala and Stockholm from 1985 onwards, and then in Uppsala, Stockholm and Copenhagen from the end of 1985—because then Copenhagen also got a device. So a research network was then constructed in Lund-Uppsala-Stockholm-Copenhagen that was really good in the 1980s. The whole direction of research was flow and later, perfusion-diffusion.*[71] *[The second line was the development of coils for neuroradiology, which was conducted in Lund.]*

The Lund group summarized retrospectively the work of that Scandinavian flow group (SFG) as the development of specific pulse sequences for "velocity mapping" (i.e. imaging of flow velocity values in a cross-section of e.g. a vessel), and the evaluation of these methods in cardiac patients.[72] Quantitative characterization of flow was the group's main line of study, and in 1987 Ståhlberg defended his dissertation on flow MRI.[73]

capturing flows in the MRI apparatus

Many of the endeavors Ståhlberg, Nordell and others engaged in were experimental and many theoretical—e.g. finding analytical expressions for the relations between flows and MR signals and mathematical means of extracting information about the flow.

Nordell and Ståhlberg's early work together with other researchers demonstrated and characterized pulsatile movements in the cerebrospinal fluid (CSF). The CSF, running through the brain's ventricles and down the spine, was known to be subjected to flows—not least, flows that blurred the details of anatomic MR images in the surrounding tissues. Nordell and Ståhlberg and what was becoming the SFG were according to themselves the first to capture that flow and integrate it in the apparatus of the MRI gaze. Synchronizing (also called "gating") MRI measurements on heartbeats, they produced a first characterization of the changing, pulsatile flow of the CSF along the heart cycle. Whether these results were quantitatively accurate was not demonstrated, however, due to the absence of other comparable studies.[74]

The Scandinavian flow group also worked on methods to "capture" blood flow: to make it visualizable with MRI. Two main lines of research were developing internationally around the mid-eighties: one was based on the effects of flow on the intensity of the MRI signal (due to protons leaving or entering the tiny volumes measured with MRI during the imaging time), and the second on the more complex effects of flow on the dispersion of protons' time behavior (called "phase" in the MRI signal).

Ståhlberg, together with his Danish colleagues Olle Henriksen and Carsten Thomsen from Hvidovre Hospital, at first adopted the former approach, which was technically more straightforward. It used available pulse sequences (those used for anatomical imaging) and added a layer of post-processing of the MRI data. Their work on simulations and tests in vitro on mechanically generated and controlled flows seemed promising at first: The measurements obtained in the physics laboratory's simulation of blood flow fell within the range of the blood flow values usually found in medical literature.[75]

However, when tested on humans and compared with blood flow measurements obtained with established methods (the invasive "indicator-dilution technique") in the same human subjects, the MRI flow values proved to be very inexact, which implied that they had no clinical value. Henriksen, Ståhlberg and their colleagues put the blame on several parts of the visualization chain: from the body itself (the pulsatile motion in the vessels) through MRI's mediation process (it was difficult to estimate the changing cross-sectional area of the vessels and the slice thickness of MRI; the design of MRI's excitation of bodily tissues induced uncertainties) to the post-processing methods (which required additional MRI measurements of the motionless blood as a reference value).[76]

Ståhlberg and the SFG then focused on the further developments of the second line of methods for MRI flow imaging (those based on "phase") for both blood and CSF, which after simulation on phantoms were successfully clinically validated.[77]

This raises the question of *what* these flows were that Ståhlberg, Nordell and others were attempting to grasp with a new MRI gaze. A plain answer—a definition—could be "macroscopic movements of bodily fluids", such as blood and the cerebrospinal fluid. But in order to be measured with MRI, these movements were conceptualized and modeled as mathematical-physical MRI objects. *Flow* referred ambiguously to the idealized entity to be measured—a velocity, i.e. a speed—and to its unmastered thick fluid referent in which linear flow and also what are usually referred to in physics as turbulences, and/or effects induced by the MRI fields in the fluids (e.g. "eddy currents") contributed to the observed changes in MRI signal that were taken to be flow velocity. These other effects—all the messy motion—were considered artifacts but hardly separable from the linear velocity in the fluids. Not least, the pulsations engendered by heartbeats caused non-linearities in the blood motion in the arteries, and in the CSF motion.

Strategies such as "cardiac gating" (synchronizing signal acquisition on heart cycle) were used in order to avoid registering those of these perturbations known to occur at given moments of the heart cycle. Still, machinery-induced phenomena such as eddy currents could not be removed in that way, which among other things justified the use of test objects, called "phantoms", to characterize the MRI gaze's built-in deviations. In other words, something first as easily and spatially abstracted as blood or CSF was not docile as an MRI object: embedded in the MRI flow were a lot of fluid motions defined as perturbations of the "true" value of the flow, but still very much part of it in the living, moving flesh.

phantoms: directing the MRI gaze towards life processes and technology

MRI flow researchers did not have the ability to observe with their eyes whether their quantitative visualizations corresponded to their objects of study—fluid velocities within the body. Because by definition, flows such as blood flow existed only *in vivo*. Unlike early anatomic MRI depictions, which could be confronted visually in experimental research and quantitatively at autopsy with the tissues they were intended to represent (cf. first part of this chapter), flow could not be verified after death, or by taking a tissue sample to analyze in the laboratory.

As in the first part of this chapter, cross-referencing was a major disciplining structure in MRI flow research, and one of the methods the SFG's researchers used to discipline MRI representations of flows. Flow-measurement techniques such as indicator-dilution technique, or Doppler echocardiography in the case of the heart, were used for in vivo correlations. However, these techniques used for cross-correlation gave only one quantitative measure of one spatial point, as opposed to MRI whose images ideally represented maps of flow in a cross-section of the body. Thus, comparison techniques served to keep MRI flows within limits of plausibility, but they could not provide a *referent* for the conducted visualizations.

One solution that the Scandinavian flow group adopted to validate their MRI developments before testing *in vivo* was to calibrate the MRI flow technology on phantoms. Phantoms were simple objects designed to mimic the characteristics to be imaged with MRI. To put it plainly, phantoms helped the researchers to get the MRI technology to work in the physics laboratory before testing it on humans. In Chapter 3 I have introduced a phantom that was used to calibrate MRI's radiological gaze: it was static and had a shape reminding of the body parts to be imaged with MRI. Similarly, when confronted with the calibration of the MRI flow, researchers had to use flowing objects.

Early phantoms for NMR measurements of flow consisted of tubes through which a fluid was circulated.[78] However, such tube phantoms were far from ideal: in those, fluids showed an inhomogeneous and complex velocity profile (predictable in the middle and messy closer to the tube walls) in the velocity ranges of blood. Nordell and Ståhlberg therefore developed their own "rotating phantom", enabling a simultaneous testing of a whole range of linear velocities.[79] Figure 30 shows the design of the phantom itself: It was based on a rotating wheel mounted between two static parts. The wheel was filled with a special gel in which flow was

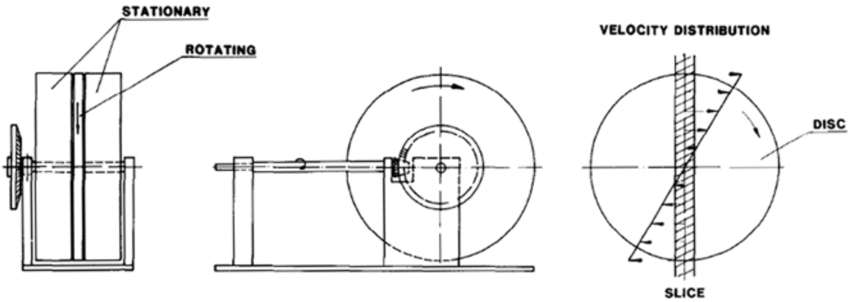
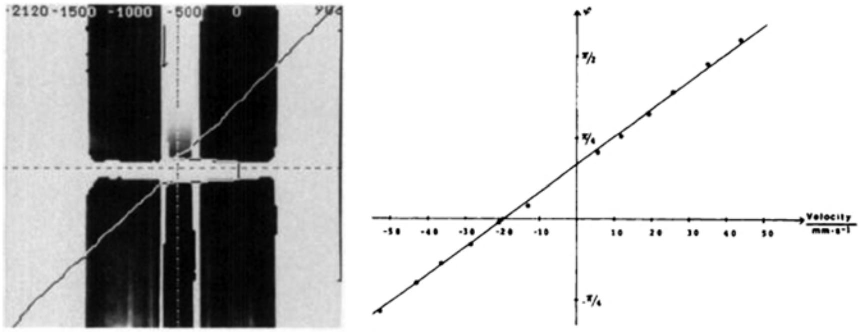


Figure 30. Nordell et al.'s rotating phantom for the calibration of MRI flows.[80]



a. b.

Figure 31. MR Image of the rotating phantom (left) and calibration curve for MRI flow measurement (right).[81]

induced when the wheel was turning. The third picture on Figure 30 shows that the flow induced in a vertical section at the level of the center of the wheel was predictable and was in a mathematically simple relation to the distance to the center of the wheel. In order to test the MRI sequences for flow measurement, the researchers produced an MR image of that vertical section, which is shown on Figure 31 (left). The picture on the right on Figure 31 illustrates that the researchers plotted the measured MRI-signal characteristic ("phase") against the theoretically calculated velocities for a set of points in the imaged vertical section. Hence they established a linear correspondence between quantitative MRI information (phase) and velocity; this relation matched theoretical results and enabled the researchers to translate the MRI-characteristic phase into velocity in further measurements, e.g. imaging/measurements *in vivo.*

One aspect of this rotating phantom is striking: whereas neck phantoms for calibrating the anatomic gaze somehow resembled a neck, the rotating phantom did not look *at all* like a blood vessel. Tube phantoms did, but

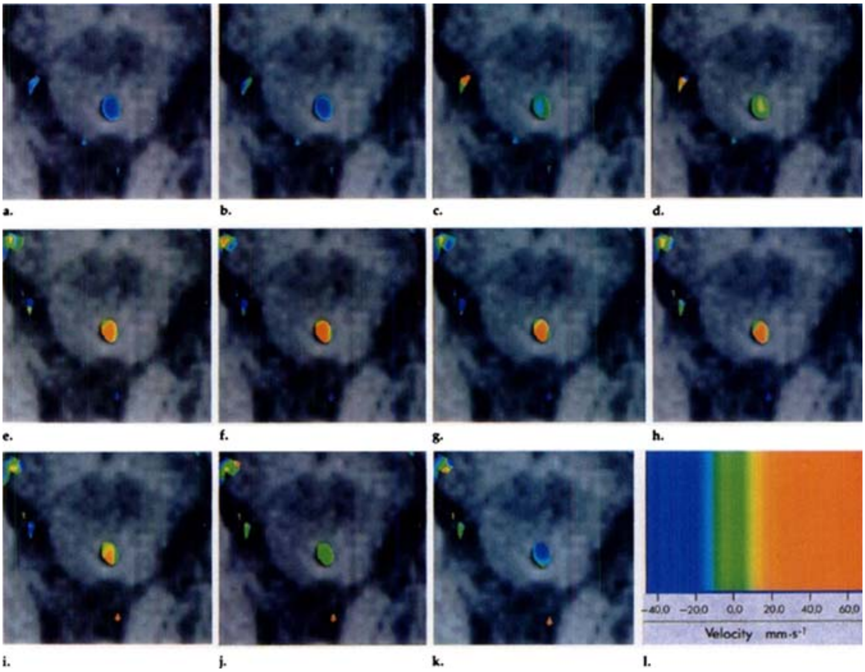


Figure 32. MR-Images of the CSF flow in the cerebral aqueduct. The CSF is located where the color stain (flow) is, in the middle of each picture. Although the series is temporal (the images follow each other with 71 ms), each of the scans is in itself a bearer of a process information.[82]

they did not work well as phantoms—because just like bodily vessels they created flow profiles which were non-linear, inhomogeneous, turbulent: they were neither predictable enough nor controllable enough. In contrast, the rotating phantom was found to be compliant with the exigencies of researchers: its flow distribution was predictable, easy to calculate, and easy to confront a single MRI image with. Moreover, the researchers could render the phantom more “like” the bodily flows it mimicked by adding components to the gel that would give it similar relaxation times as e.g. blood or CSF.

This exemplifies what the phantom was taken as a surrogate for: disembodied flow, in both its very material and very abstracted (quantified) form.

This is important for several reasons. First, the flows produced by the phantom did not change over time: they were different in different parts of the apparatus, but they were constant during the time of the experiments. This shows that what was the object produced with MRI was a process itself, a material *and* dynamic object, containing a temporal dimension of its own.

The MR image of the phantom displayed in Figure 31 informs the reading of the MR images of CSF flow *in vivo* reproduced in Figure 32. Figure 32 shows a series of MR pictures of the CSF flow produced after calibration on the phantom. The main part of the pictures is displayed in a gray scale; it looks mostly similar throughout the images and stands for the cross-sectional anatomy of the surroundings of the cerebral aqueduct. In contrast, the small circular zone in the center of the pictures, which corresponds to the flow in the CSF, is colored. The last picture on Figure 32 (bottom right) gives the arbitrary color-coding scale of the CSF flow: a green point represents a zero velocity (no flow), whereas warm colors (yellow through orange) stand for flows downwards and cold colors (blue) signify flows towards the brain. The nuances of colors coded for the velocity of the flow. The color map of the CSF is not uniform in each picture, indicating a spatial distribution of flows at each moment of image-making. Each isolated picture thus embodies information about the configuration of CSF flows at the picture's time of imaging. The temporal dimension re-embodied in each MR image is thus the same as that of the phantom: a processual temporality.

If we now consider Figure 32's image series as a whole, another temporality emerges. The original image caption explains that these eleven pictures are produced at regular intervals (71 milliseconds) of the heart cycle, thus representing, as a whole, the behavior in time of the CSF through one heart cycle (one heartbeat). This indicates to the reader that the series of eleven pictures should be read as a temporal series—but the temporality at stake is different from that contained in each picture alone. A cyclic temporal dimension was thus superimposed on each picture's processual temporality by lining up pictures taken through a heart cycle and by attaching to it a set of time notations.

Two temporalities were hence collapsed into the MRI snapshots which were made bearers of simplified dynamic information about the materiality of bodily life. These temporalities were distinct and relied on two different representation schemes: flow "itself" as a process built and represented in a single picture with a color scheme of its own; and the cyclic fluctuations of flow along the beating heart's timeline, constituted through the alignment of pictures in a temporal series as a physiological meta-process: the changes in time (cycle) of a dynamic entity (flow). The pictorial conventions followed in Figure 32 are common in physiology: anatomy was represented on the flow images as the spatial site of physiological processes, and the *set* of images organized as a series of consecutive snapshots reminds of the cinematographic techniques dear to early twentieth-century physiologists.[83]

The researchers of the SFG were thus able to discipline the flow within physiology's gaze by integrating physiology's temporalities and representation frames in their development and practice of MRI techniques.

A second reason why the phantom's "surrogacy" is critical is that working with the phantom's material but disembodied flows directed again the MRI gaze at the technology itself. This echoes with the first part of this chapter, and with Lisa Cartwright's analysis of the early microscopic gaze. Concerned with microscopists' deployment of a range of test objects—taken from the "natural" world and later, constructed from inorganic material—Cartwright writes:

> The introduction of the test object is significant because it suggests that from the early nineteenth century forward microscopists were more interested in verifying the accuracy of their instruments than in verifying the representational integrity of the microscopic scene they saw. It could be said that the primary focus of the scientific gaze in this context is the instrument itself and not the object viewed. [---] But while it may be argued that this focus on the instrument was circumstantial (there being no available "promicroscopic" real), I would argue that this attention to the instrument is a symptomatic response to the unmanageability of the object.[84]

"A symptomatic response to the unmanageability of the object"—MRI researchers' efforts to discipline the MRI flow with material models (phantoms) and with mathematical-physical models (implemented in pulse sequences and post-processing) were efforts to handle their highly unstable object which they could not directly shape or manage. Hence the displacement of the researchers' managing attempts from the body to MRI's mechanisms of mediation.

conclusion: disciplining the unruly objects of the living matter

Lisa Cartwright writes, about the nineteenth century's new visual culture of microscopy: "[A] point of instability was always the lack of a reassuring view by the eye of the territory charted. In the absence of a conventionally perceptible field, microscopists were burdened with the knowledge that what they saw through the viewfinder might still be a distortion—or worse yet, an image artifact [---].[85]

I have shown above that the SFG researchers were confronted with a similar issue, which generated a similar anxiety and a need to control the object through a focus on technology's representation processes and on laboratory objects before the living body.

To use Evelyn Fox Keller's semantic distinction, phantoms were not as much models *of* flow as models *for* making the whole representation-flesh apparatus work in an intelligible and controllable way. In contrast, the mathematizations of flow were both models *of* bodily phenomena and models *for* translating them into images and numbers. To put it plainly, Fox Keller's point is that scientists use "models *for*" to make things work, and do not take them for the "real thing".[86] This applies to our examples: Phantoms and mathematical-physical models, as models *for*, disciplined the object of study (MRI flow) by helping to reduce it to its physically intelligible components (velocity and the temporality of the heart cycle). What phantoms did was thus to help materially constitute "MRI flow" as a technomedical working object: the privileged object of an MRI's physiological gaze.

CONCLUSION: STRUGGLING WITH BLIND TECHNOLOGIES

The two parts of this chapter have focused on experimental NMR/MRI practices. The MRI researchers' numerical-technological work I have explored here illustrates a fundamental epistemological uncertainty about *what* the MRI gaze made visible, intelligible, manageable. The practice of cross-referencing signified the fundamental instability of MRI representations. This instability—a recurrent theme also in previous chapters—was due to the lack of unambiguous referent; but also to the differences between local settings for MRI examinations and experiments; and to the open-endedness of the ways images could be generated with MRI.[87]

My intention in this last chapter has been to foreground the messiness of the phenomenon that the Lund MRI group and the SFG attempted to grasp with MRI, and to highlight some of the strategies they deployed to manage it. I have argued that Lund and SFG's MRI researchers came to terms with the indocile bodily matter by mobilizing the cross-referential networks of the laboratory—instruments, methods, representations, practices. The rotating phantom for calibration in flow imaging may then be read as a case where the MRI researchers constructed a compliant, reliable cross-referencing object when they lacked a sufficient network to enable them to stabilize the meaning of MRI representations. As a result, the NMR/MRI gaze was disciplined and made to align with pathology's gaze (and thereby, with an ideal anatomical body) and physiology's gaze. The NMR/MRI gaze constituted in these settings thus realized a merging of the pathological laboratory's quantitative gaze with radiology's visuality and physiology's own set of conceptions and representations of bodily life: its visual temporalities.

This concludes the series of Chapter 3 through 6 in which I have shown that the representations created with MRI were unstable and that their use in radiology, psychiatry and the laboratory was the result of actors' work to tame MRI into the principles, methods and practices of radiology's, psychiatry's and laboratory gazes.

In the character cast of this specific history of MRI, I have given researchers the role of active observers who attempted to build their own instruments of blind vision. The shaping of these MRI gazes required the researchers to tame MRI's invisible elements (magnetic fields, sequences of gradients and radio waves, resonance phenomena, etc) and managed the obscure body they wanted to observe through its tissues and protons, in its materiality and intermolecularity.

This narrative of struggle is not innocent; neither is it innocent that I have constructed it in resonance with Lisa Cartwright's study of early microscopy. This history of the struggle of MRI demonstrates that the relation between the observer and the bodily objects of study was shaped in the making of the MRI gaze. If we are to understand the way the MRI gaze operated, we need to take a look at how researchers and clinicians attempted to discipline the apparatus of the gaze, and the transfers of autonomy and judgment from the observer to the machine. Researchers' struggles to remove artifacts and to create certainty as to what MRI really showed signify that MRI's electromagnetic waves, magnetic fields and bodily objects were endowed with something like agency. MRI researchers disciplined this almost-agency through the cross-referential networks of, for example, radiology and the laboratory.[88]

The taming of the MRI gaze allowed the researchers' transfer of autonomy from human intervention and judgment to the devices' coils and pulse sequences (imaging sequences of magnetic gradients and radio waves), i.e. into MRI's material apparatus. MRI users were thus far more than observers interpreting scans. The position of MRI users was instead one of technomedical designers who chose, created, and used pulse sequences to produce MRI representations that would bring out specific bodily objects (such as tumors, brain lesions, flows) as real and visible by, for instance, building in contrasts that kept apart the bodily objects of pathological anatomy (cf. Chapter 3). Such transfers of autonomy and judgment from a hypothetical observer position to MRI's technological apparatus were an important feature of the shaping of the MRI gaze. Agency schemes and observer positions are constitutive of the history of the visualities performed with MRI; they were negotiated—reproduced and re-cast—in the shaping of MRI's mediations.

[7] a kaleidoscope of gazes

Media scholars Jay David Bolter and Richard Grusin have introduced the concept of *remediation*—the mediation of mediation.[1] With this they argue that no new media is really new, in the sense that new media always emerge in relation to existing media, which they most often re-produce, re-use and refashion. Bolter and Grusin argue that "[n]ew digital media are not external agents that come to disrupt an unsuspecting culture. They emerge from within cultural contexts, and they refashion other media, which are embedded in the same or similar contexts."[2]

Whereas authorities' early decisions momentarily defined MRI as a radiological tool for immediate clinical use, huge efforts were deployed in numerous Swedish universities and hospitals which, over time, performed a multitude of shapings of MRI's gaze. Researchers from different scientific and medical subcultures made MRI see radiology's anatomical body along the clinic's time of pathology; to work as psychiatry's connecting system between brain anatomy, mental illness and society; to perform the pathological laboratory's gaze on the living body instead of samples; and to capture and reproduce physiology's framing of bodily life in time and space. The microhistories told in this dissertation render but a small part of what was done with MRI in its early years in Sweden. But they allow one first comment: MRI's vision was constituted as a multitude of gazes.

In the case of the present study, Bolter and Grusin's argument therefore implies that the novel MRI gaze must be understood within the context of its contemporary technological subcultures of science and medicine, and more specifically, the local contexts of existing medical practices and mediation methods (such as radiological technologies of anatomical imaging in radiology departments, or the network of histological tools in the pathological laboratory). The processes of shaping the MRI gaze that I have described in this study then appear as a remediation of existing gazes, their methods and frames of knowledge.

At first glance, this might suggest that imaging is a conservative technological mode, meaning that MRI users imaged and saw what they already knew they could see. Did MRI simply reproduce existing gazes? If not, what was novel in MRI?

In the following pages I shall first draw together the conclusions of different chapters about the shaping of MRI gazes. I will then conclude by commenting on MRI's place in the fragmented world of technomedicine.

remediating technomedical gazes

I have argued that the early interests in MRI expressed by Swedish researchers were hierarchized through the Swedish Medical Research Council's decision to fund the purchase of one MRI scanner for a national evaluation of its clinical value. In this decision, during the evaluation and in the arguments produced by MRI users around the mid-1980s, MRI was acknowledged both as a radiological imaging technology, producing crisp anatomical pictures of the body, and as a laboratory technique for experimental research. The former was valued higher than the latter—although experimental MRI research was recognized as an important field for the future.

I have interpreted these negotiations as boundary-making, and made the point that sustaining boundaries requires continued work. Therefore I have turned to the practices of MRI, in selected research laboratories and clinical settings, to explore a fundamental problem: the representations (images/measurements) that could be produced with MRI were anything but obvious—MRI users had to stabilize what it was that they saw on the new scans, or through these, measured from the body. My history of the shapings of the MRI gaze epitomizes a struggle between researchers—users—and a highly undefined and open-ended referent, which I have referred to as the MRI body. By focusing on the introduction of MRI in research practice in Sweden, I have shown that a crucial part of the work conducted with MRI in the 1980s aimed to make MRI congruent with different, existing technomedical gazes.

Firstly, the MRI gaze had to be intelligible within the frame of existing technologies and ways of seeing the body. I have argued that researchers achieved this by producing MRI representations of different kinds and systematically correlating or comparing them within cross-referential networks. The techniques mobilized in these situated networks were for instance: radiological and anatomical depictions, neuropsychological tests, microscope imaging and histopathological analysis, and specifically built phantoms.

Secondly, researchers reproduced existing gazes in the making of representations (pictures and measurements) with MRI. I have first shown that MRI users realized this reproduction by optimizing MRI representations along the principles of clinical, radiological, anatomical vision. I have then given examples of how MRI users established categories of NMR/MRI values along histopathological or psychiatric categories of tissues and persons. In my study of the laboratory gaze, I have argued that NMR/MRI researchers also calibrated the working object of NMR/MRI (values obtained from samples) on an ideal anatomical body.

Not only visuality and categories of the normal and the pathological were reproduced in the shaping of the MRI gaze; MRI users also integrated their technomedical *time frames* in the production and interpretation of MRI scans. In Chapter 5 I have shown how an idealized lifetime was made part of the MRI gaze in the continuity of neuropsychiatric studies of ageing. Chapter 6 has made visible how NMR/MRI researchers made the postmortem time of the laboratory transparent, and how they reproduced physiology's processual time frames and cycles in the construction of flow-imaging techniques. The clinical time of pathology was touched upon in Chapter 3, and further embodied by the time of HIV infection in Chapter 4. The specific time at stake in the temporal series of MRI scans of HIV-positive patients was a time bearer of causality, since HIV was dominantly thought to cause AIDS; in a sense, these MRI scan series worked as an image of an inevitable progression of the disease towards dementia.

I have also shown that anatomy recurrently worked as a frame for the exploration of the MRI gaze in the settings of psychiatry and the laboratory. Among other things, I have suggested that the principles of pathological anatomy were repeatedly integrated in the interpretation and production of MRI representations: anatomy's notational "geography" of the body, anatomy's material visuality based on separation principles, and anatomy's epistemology which sought the traces of the disease in the materiality of the body.

However, what at first seemed to be radiology's anatomical dominance in the shaping of the MRI gaze was challenged by, among other applications, the integration of a laboratory gaze in MRI's vision.

a kaleidoscope of gazes

Bolter and Grusin's argument reformulates the novelty of new media as a refashioning of existing mediations:

> What is new about new media comes from the particular ways in which they refashion older media and the ways in which older media refashion themselves to answer the challenges of new media.[3]

Similarly, I have shown that the MRI users created and used MRI representations not only along existing frames of knowledge, but most often at the crossroads of existing gazes. For instance, anatomy's body was a crucial frame for the laboratory work described in Chapter 6, and quantitative measurement studies were used as means to better interpret and design radiological MRI scans according to pathological anatomy's principles of visual separation.

A more complex but more striking case is that of the integration of MRI in psychiatric practice, which I have read as a history of the remediation of both radiology's anatomical gaze and a specific psychiatric gaze, for example in the context of HIV/AIDS epidemics. I have argued that the introduction of MRI at St. Göran's Hospital marked an "anatomization" of its psychiatric practice. But the same MRI users at St. Göran's produced MRI anatomies that were hybrids of a laboratory gaze and of radiology's anatomical gaze. The duality between on the one hand, anatomy's spatial, visual and inert depiction of the body, and on the other, MRI's quantitative laboratory information was reflected in psychiatrists' description of the brain scans of HIV patients and in their explanations of the novel kind of brain research that MRI's quantitative values enabled.

Resulting remediations such as MRI scans of the brains of HIV-infected patients produced new configurations of existing gazes—and of their epistemologies: In brain imaging of HIV-positive patients, researchers performed an MRI gaze that reproduced the epistemology of anatomy, as that gaze sought and produced the visible traces of a disease in the materiality of the flesh (brain). But the same MRI gaze also reproduced the quantitative epistemologies of the laboratory which categorized brain tissue as normal or abnormal on the basis of earlier histopathological results. Moreover, the representation frames mobilized in the MRI scans of the brains of HIV-positive people were a hybrid form of realism: anatomy was used as a visual support to map laboratory-like values; but these values were taken as truthful representations of anatomy itself.

If anatomy recurrently worked as an underlying frame for the exploration, interpretation and production of MRI's visuality, MRI anatomy was not a straightforward copy of existing anatomies. Rather, anatomy's material visuality provided a site for the production of novel facts at the intersection of existing gazes. Through the practices of shaping MRI gazes, anatomy was systematically remediated: reproduced and reconfigured.

The novelty of facts and representations in MRI can thus be understood as the reconfiguration of the relations between existing frames of knowledge, practices and representation—between existing gazes. MRI's uniqueness or novelty was thus not so much the principles on which its representations of the body were based, but rather the way it remediated existing gazes and set these in new, specific relations to each other. MRI thus worked as a kaleidoscope of gazes: materializing new relations between existing frames of knowledge and methods in the production of technomedical facts.

notes

PROLOGUE: MRI'S HEYDAY

[1] Ringertz, Hans, *Presentation Speech for the Nobel Prize in Physiology or Medicine 2003* (2003), http://nobelprize.org

[2] Ibid.

[3] Ibid.

[4] *Nobel Prize in Physiology or Medicine 2003, Press Release* (2003), http://nobelprize.org

[5] Ringertz, *Presentation Speech*

[6] van Dijck, José, *The Transparent Body: A cultural analysis of medical imaging* (Seattle: University of Washington Press, 2005), p.3-5.

CHAPTER 1: INTRODUCTION

[1] "Diagnostic imaging", in *Encyclopædia Britannica Online* (2007), http://www.britannica.com, February 3, 2007. Emphasis in original.

[2] Yoxen, Edward, "Seeing with Sound: A Study of the Development of Medical Images" in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. Wiebe E Bijker, et al. (Cambridge, Mass.: MIT Press, 1997 [1987]).

The fact that the quantitative acoustic information was itself visually represented—as different curve profiles observed in real time on oscilloscopes or printouts—does not really count here: seeing and interpreting abstract time profiles of signal response was not considered the same thing as *seeing* a picture of an inner organ. Radiology's utopia of corporeal transparency accounts for specific kinds of visualization—not for all of medicine's visual practices or visual evidence.

[3] William Oldendorf's lecture at St. Göran's Hospital, Stockholm (DVD copy of original video recording): *The Past, Present and Likely Future of NMR - St. Göran Lecture nr 81, March 27, 1985*, Lennart Wetterberg private archives.

[4] Sources: Clarke, Edwin and Kenneth Dewhurst, *An Illustrated History of Brain Function: Imaging the Brain from Antiquity to the Present* (San Francisco: Norman Pub, 1996 [1968]), p.105; Larissa Bilaniuk's presentation of NMR imaging: *St. Göran's Hospital, Stockholm, February 15, 1984 (DVD copy of original video recording),* Lennart Wetterberg private archives. The MRI-scan has been flipped horizontally (i.e. mirror-imaged) to allow better comparison between the two illustrations. Cf. Figure 11 in Chapter 4.

[5] Amsterdamska, Olga and Anja Hiddinga, "The Analyzed Body" in *Companion to Medicine in the Twentieth Century*, eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000]), p.418.

[6] Clarke and Dewhurst, *An Illustrated History of Brain Function* , p.38, 56.

[7] Ibid., p.56.

[8] Martensen, Robert L, *The Brain Takes Shape: An early history* (Oxford, New York: Oxford University Press, 2004); Clarke and Dewhurst, *An Illustrated History of Brain Function* .

[9] "Anatomy", in *Encyclopædia Britannica Online* , November 15, 2007.

[10] A good cultural history of anatomy, also accessible to laypersons, is the book/post-exhibition catalog *Dream Anatomy* written by curator and historian of medicine Michael Sappol: Sappol, Michael, *Dream Anatomy* (Bethesda, Md: U.S. Dept. of Health and Human Services, National Institutes of Health, National Library of Medicine, 2006). Cf. also e.g. Laqueur, Thomas, *Maxing Sex: Body and Gender from the Greeks to Freud* (Cambridge, MA; London: Harvard University Press, 1992 [1990]); Martensen, *The Brain Takes Shape* ; Clarke and Dewhurst, *An Illustrated History of Brain Function* .

[11] Blume, Stuart S, *Insight and Industry: On the Dynamics of Technological Change in Medicine* (Cambridge, London: The MIT Press, 1992), p.216-220.

[12] Amsterdamska, Olga and Anja Hiddinga, "The Analyzed Body" in *Companion to Medicine in the Twentieth Century*, eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000]), quote p.431. Cf also Reiser, Stanley Joel, *Medicine and the Reign of Technology* (Cambridge: Cambridge University Press, 1978). On the twentieth century technification of medicine, see also Blume, Stuart S, "Medicine, Technology and Industry" in *Companion to Medicine in the Twentieth Century,* eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000]). For a criticism of the epistemological and ontological consequences of notions of fragmentation and fragmented body, see Mol, Annemarie, *The Body Multiple: Ontology in medical practice* (Durham & London: Duke University Press, 2002).

There are Swedish examples of the medical community's foregrounding and criticism of the fragmentation of medicine, which, they argue, is due to the technification of care in the 1960s and 1970s. For instance: "We have been getting an increasingly specialized health care during the last decades, in pace with the development of research and technology. Both staff and patients have experienced that the human being has 'disappeared' from health care. We have today 44 medical specialties and 200 subspecialties, each of which is interested in one small part of the human body. [...] As a reaction to this high-technocratic specialist care, the demand for a 'total view' has grown stronger and stronger." Boethius, Eva, "Helhetssynen - ett diffust mål för sjukvården. Människosyn och ekonomiska faktorer styr mera" *Läkartidningen* vol.80 (1983), 1185-1187, my translation.

[13] A few titles in the history of X-rays and radiology are: Pasveer, Bernike, "Knowledge of Shadows: The Introduction of X-ray images in Medicine" *Sociology of Health and Illness* vol.11 (1989), 360-381; Pasveer, Bernike, *Shadows of Knowledge. Making a Representing Practice in Medicine: X-ray Pictures and Pulmonary Tuberculosis, 1895-1930* (Amsterdam: University of Amsterdam, 1992); Jülich, Solveig, *Skuggor av sanning: Tidig svensk radiologi och visuell kultur* (Diss.; Linköping: Linköpings universitet, 2002). Parts of Lisa Cartwright's work also deal with X ray's visual culture: Cartwright, Lisa, *Screening The Body: Tracing Medicine's Visual Culture* (Minneapolis, London: University of Minnesota Press, 1997 [1995]). Both Bettyann Holtzmann Kevles and Stuart Blume begin their books in the history of the development of medical imaging technologies with chapters on X-ray: Blume, *Insight and Industry* ; Holtzmann Kevles, Bettyann, *Naked to the Bone: Medical Imaging in the Twentieth Century* (Reading, MA: Addison-Wesley, 1997).

[14] Blume, *Insight and Industry* ; Holtzmann Kevles, *Naked to the Bone* .

Sociologist Amit Prasad has also recently published a detailed study of three actors' contributions to the "invention" of MRI with the focus on controversies and authorship: Prasad, Amit, "The (Amorphous) Anatomy of an Invention: The Case of Magnetic Resonance Imaging" *Social Studies of Science* vol.37 (2007), 533-560.

Grant, David M. and Robin K. Harris (eds.), *Encyclopedia of Nuclear Magnetic Resonance, Vol.1* (New York: Wiley, 1996) provides an internalist history of the development of magnetic resonance technologies, among which MRI. An internalist history of brain imaging technologies has also been written by psychiatrist and neurologist William Oldendorf in

1980 and mentions the early days of MRI: Oldendorf, William H., *The Quest for an Image of the Brain* (New York: Raven Press, 1980). Mattson, James and Merrill Simon, *The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI* (Ramat Gan, Israel: Bar-Ilan University Press, 1996) offers a series of biographies of the pioneers of NMR and MRI. The Nobel Lectures by Paul Lauterbur and Peter Mansfield provide oral-history accounts of the early development of NMR imaging. Lauterbur, Paul, *All Science is Interdisciplinary - From Magnetic Moments to Molecules to Men. Nobel Lecture, December 8, 2003* (2003), http://nobelprize.org; Mansfield, Peter, *Snapshot MRI: Nobel Lecture, December 8, 2003* (2003), http://nobelprize.org.

[15] In his Nobel lecture in 1952, Felix Bloch, one of the scientists who had demonstrated the principle of magnetic resonance in 1945, described relaxation phenomena as follows: "The establishment of thermal equilibrium demands the transfer of the energy released by the partial orientation of the nuclear moment into heat, and it can take place only through interaction of these moments with their molecular surroundings. The strength of this interaction determines the time interval required for the nuclear moments to adjust themselves to the equilibrium conditions; it is measured by the «relaxation time» [...]." Bloch, Felix, *The Principle of Nuclear Induction: Nobel Lecture, December 11, 1952* (1952), http://nobelprize.org.

[16] Odeblad, Erik and Gunnar Lindström, "Some preliminary observations on the proton magnetic resonance in the biologic samples" *Acta Radiologica* vol.43 (1955), 469-476

[17] For a recent overview and interpretation of the disputes about the invention of MRI, see Prasad, "The (Amorphous) Anatomy of an Invention" .

[18] Blume, *Insight and Industry* , p.192-194; 213; 217.

[19] Damadian, Raymond, "Tumor Detection by Nuclear Magnetic Resonance" *Science* vol.171 (1971), 1151-1153; Blume, *Insight and Industry* , p.192-193

[20] Blume, *Insight and Industry* , p.195-196; Lauterbur, *Nobel Lecture* . I do not account for all the turns in the 1970s' developments here—the interested reader may rather read existing literature on the topic—but instead focus on the few lines that are of interest to my study. About more MRI research groups and developments, see literature on the history of MRI listed in note 14.

[21] Blume, *Insight and Industry* , p.195-199.

[22] Ibid., p.199-215. Quote p.195. About the issue of shortening imaging time, see also Mansfield, *Nobel Lecture* .

[23] Blume, *Insight and Industry* , p.216-220. Quote p.218.

[24] Ibid., e.g. p.206; 219.

[25] Holtzmann Kevles, *Naked to the Bone* , p.188-189.

[26] Ibid., p.173-200.

[27] Joyce, Kelly, "From Numbers to Pictures: The Development of Magnetic Resonance Imaging and the Visual Turn in Medicine" *Science as Culture* vol.15 (2006), 1-22, p.3.

[28] Ibid.

[29] In addition to the works presented here, forthcoming works by anthropologist Yutaka Yoshinaka (Danmark) and sociologist Regula Burri (Switzerland) problematize the production of clinical knowledge and bodies with MRI. Cognitive anthropologist Morana Alač has published ethnographic analyses of cognitive scientists' negotiations of meanings in the use and interpretation of visual representationns produced with functional MRI (fMRI): Alac, Morana, "Negotiating Pictures of Numbers" *Social Epistemology* vol.18 (2004), 199-214; Alac, Morana and Edwin Hutchins, "I See What You Are Saying: Action as Cognition in fMRI Brain Mapping Practice" *Journal of Cognition and Culture* vol.4 (2004), 629-661.

[30] Haraway, Donna, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991).

[31] Prasad, Amit, "Making Images/Making Bodies: Visibilizing and Disciplining through Magnetic Resonance Imaging (MRI)" *Science, Technology and Human Values* vol.30 (2005), 291-316.

[32] Joyce, Kelly, "Appealing Images: Magnetic Resonance Imaging and the Production of Authoritative Knowledge" *Social Studies of Science* vol.35 (2005), 437-462.

[33] Foucault, Michel, *Naissance de la clinique* (Paris: Presses universitaires de France, 2000 [1963]). With a few exceptions I will refer to the following translation by A.M. Sheridan in this dissertation: Foucault, Michel, *The Birth of the Clinic: An Archaeology of Medical Perception* (London: Routledge, 1991 [1963]).

[34] Armstrong, David, "Bodies of Knowledge: Foucault and the Problem of Human Anatomy" in *The Body: Critical Concepts in Sociology*, eds. Andrew Blaikie, et al. (London: Routledge, 2004), p.109. Armstrong writes: "*The Birth of the Clinic* is concerned with 'le regard' of medicine: in part this translates as the way medicine has perceived things, the way things have looked or seemed. In addition, 'le regard' is also the technique by which medicine came to have knowledge of bodies, that is came to see their interiors, organs, tissues, consistancies, and variations: hence the translation, 'the gaze'."

[35] Weimarck, Torsten, "Kroppen, och den anatomiska kroppen" in *Kroppen: Konst och vetenskap*, ed. Lena Holger (Stockholm: Nationalmuseum, 2005), p.28 (my translation, emphasis in original).

[36] Ibid., p.30-31 (my translation, emphasis in original). Cf. also Michael Sappol's words: "Anatomy is our inner reality. Anatomy is us. Even if we don't have formally studied it, even if we don't know all the details, we carry around with us an anatomical image of self, a pocket map that divides us into regions and territories, with internal place names and borders and topographical features. And this anatomical self-image has a history—which is the history of anatomical representation—a long history of collaboration and negotiation between anatomists, artists, engravers, patrons, printers, and readers. Until the invention of X-ray imaging, sonograms, CT scans, MRIs, and the like, the only way to see into ourselves was through the dissection of dead human beings. The dissected cadaver was our mirror." Sappol, *Dream Anatomy* , p.3-6.

[37] Weimarck, "Kroppen, och den anatomiska kroppen" , p.43 (my translation, emphasis in original).

[38] Foucault, *Birth of the Clinic* , p.126, 135-136, 139-140, 162-163.

[39] Ibid., p.137: "A more precise historical analysis reveals a quite different principle of adjustment [...]: it bears jointly on the type of objects to be known, on the grid that makes it appear, isolates it and carves up the elements relevant to a possible epistemic knowledge (*savoir*), on the position that the subject must occupy in order to map them, on the instrumental mediations that enables it to grasp them, on the modalities of registration and memory that it must put into operation, and on the forms of conceptualization that it must practice and that qualify it as a subject of legitimate knowledge. What is modified in giving place to anatomo-clinical medicine is not, therefore, the mere surface of contact between the knowing subject and the known object; it is the more general arrangement of knowledge that determines the reciprocal positions and the connexion between the one who must know and that which is to be known." Emphasis in original.

[40] Cartwright, *Screening The Body* , p.11. Cf. Foucault, *Birth of the Clinic* p.166-167.

[41] Cartwright, *Screening The Body* ; Dumit, Joseph, *Picturing Personhood: Brain Scans and Biomedical Identity* (Princeton, N.J.: Princeton University Press, 2004); Beaulieu, Anne, *The*

Space Inside the Skull: Digital Representations, Brain Mapping and Cognitive Neuroscience in the Decade of the Brain (Diss.; Amsterdam: University of Amsterdam, 2000).

[42] About modes of seeing as constitutive of professions, see Goodwin, Charles, "Professional Vision" *American Anthropologist* vol.96 (1994), 606-633.

[43] See similar arguments against a professions' approach in Keating, Peter and Alberto Cambrosio, *Biomedical Platforms: Realigning the normal and the pathological in late-twentieth-century medicine* (Cambridge, M.A., London, England: The MIT Press, 2003), p.17-20.

[44] Mitchell, William J., *The Reconfigured Eye: Visual Truth in the Post-Photographic Era* (Cambridge, MA; London: The MIT Press, 2001 [1994]), e.g., p.3-57.

[45] Beaulieu, *The Space Inside the Skull* , p.14-23. Quote p.22.

[46] Waldby, Catherine, *The Visible Human Project: Informatic Bodies and Posthuman Medicine* (London; New York: Routledge, 2000); Waldby, Catherine, "The Visible Human Project: Data into flesh, flesh into data" in *Wild Science: Reading feminism, medicine and the media,* eds. Janine Marchessault and Kim Sawchuk (New York: Routledge, 2000); van Dijck, *The Transparent Body* . I won't use "digital anatomy" as a concept nor as a definite context because I regard it as problematically suggestive. The phrase "digital anatomy" is based on the semantic erasure of radiology, the set of methods of production of the very anatomy at stake. All that is left is anatomy (a description/organization of the body) in a digital form.

[47] For a general historiography of the body, see Jenner, Marc SR and Bertrand O Taithe, "The Historiographical Body" in *Companion to Medicine in the Twentieth Century,* eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000]).

[48] Dumit, *Picturing Personhood* , 157.

[49] About hermeneutics of suspicion in the history of contemporary science, see Söderqvist, Thomas, "Existential projects and existential choice in science: science biography as an edifying genre" in *Telling lives in science: essays on scientific biography,* eds. Michael Shortland and Richard Yeo (Cambridge: Cambridge University Press, 1996).

[50] Daston, Lorraine and Peter Galison, "The Image of Objectivity" *Representations* (1992), 81-128.

[51] See also Mol, *The Body Multiple* ; Cartwright, *Screening The Body* .

[52] I will approach the technomedical gazes at stake in the history of MRI as *material subcultures* rather than visual or epistemic subcultures—epistemological stances/practices are a part of these material subcultures. In order to account for the materiality of the MRI gaze and in line with Peter Galison's work on microphysics, *Image and Logic: A Material Culture of Microphysics* (Chicago and London: The University of Chicago Press, 1997), I follow the material subcultures of technomedicine, tracing MRI's use as a way of access to the interaction between divergent gaze-related practices, and between those and the social context they were embedded in. Galison's conceptual apparatus highlights how actors belonging to different professional subcultures with incompatible theories interacted in the material/instrumental practice of microphysics. Galison thus finds a meso-level of analysis, drawing a link between physics' global theories or professional cultures and local, embodied, specific but crucial uses of instruments and production of facts. Similarly, the interactions of different material subcultures around common instrumental technologies are processes by which technomedicine works as a whole, although it is made of a patchwork of specializations and disciplines with divergent understandings and practices of the body.

[53] Prasad, "Making Images/Making Bodies"

[54] Cartwright, *Screening The Body* , e.g. xi-xiv.

[55] Dumit, *Picturing Personhood* , p.25.

[56] Ibid., p.26.

[57] Ibid., p.34; 27.

[58] Ibid., p.34.

[59] I have conducted the following interviews, of which a few are used as sources in this dissertation (the institutions mentioned are those to which these actors belonged in the 1980s): Anders Hemmingsson, Anders Ericsson, Göran Sperber, Bo Jung, Britt-Marie Bolinder, Jan Weis, Lars Johansson, Hans Gref, Solweig Schwartz, Nils Stocksén (Uppsala University Hospital / Uppsala County Council), Lennart Wetterberg, Ingrid Agartz, Lars-Olof Wahlund (St. Göran's Hospital / Karolinska Institute), Bertil Persson, Freddy Ståhlberg, Holger Pettersson, Erik Boijsen (Lund University Hospital), Bo Nordell (Karolinska University Hospital Solna), Tore Scherstén, Håkan Eriksson (MFR), Lars Filipsson, Lars Lundqvist (Siemens-Elema), Peter Stilbs (KTH), Silas Olsson (SPRI), Hannibal Sökjer (Linköping University Hospital), Gunnar Hofring (Federation of County Councils), Peter Aspelin, Stefan Skare (Karolinska University Hospital, Solna).

[60] For instance: Söderqvist, Thomas (ed.) *The Historiography of Contemporary Science and Technology* ([Amsterdam], The Netherlands: Harwood Academic Publishers, 1997); Doel, Ron and Thomas Söderqvist (eds.), *The Historiography of Contemporary Science, Technology and Medicine: Writing Recent Science* (London, New York: Routledge, 2006)

[61] To use a precise terminology from Herbert Rubin & Irene Rubin's *Qualitative Interviewing*, I have conducted what is called *responsive interviewing,* i.e. interviews where "the researcher is responding to and then asking further questions about what he or she hears from the interviewees rather than relying on predetermined questions." (p.vii) Rubin and Rubin categorize interviews along two dimensions: scope (open-ended, semi-structured or narrow interviews) and focus (interviews focusing on meanings and understandings, or on events and processes, respectively). As far as possible, my interviews have been semi-structured (i.e. with an intermediate scope) and with a focus on both understandings and events; some of them narrower and focused on events and processes ("investigative interviewing"). See Rubin, Herbert J and Irene S Rubin, *Qualitative Interviewing: The Art of Hearing Data* (Thousand Oaks, CA; London; New Delhi: Sage Publications, 2005), p.5.

[62] Some of the interviews have been recorded and transcribed. The transcript has been sent to the informant for possible editing or anonymization in the cases I have intended to quote from it. In other cases, a manuscript of the chapters where I quote from an interview has been sent to the informant for comments and final consent.

[63] PubMed's site is: www.pubmed.org. (Accessed on 2002 through 2007).

[64] On the problems posed by the sheer amount of sources, among others scientific publications, in the history of contemporary science and technology, see Thomas Söderqvist's chapter in Söderqvist (ed.) *The Historiography of Contemporary Science and Technology* (p.4-5) and M. Susan Lindee's chapter in the same book (e.g. p.41). See also Jeff Hughes' criticism of that point in the same book (p.23-24).

[65] Galison, Peter, *Image and Logic: A Material Culture of Microphysics* (Chicago and London: The University of Chicago Press, 1997), p.55-56. Quote p.56. See also Cartwright for examples of "microhistory of a technical culture", Cartwright, *Screening The Body* , p.83.

[66] For a short non-Anglo-Saxon history of MRI, and about the relation between Eurocentrism, US/UK/Western and Indian MRI research and science, see Prasad, Amit, "Beyond Modern vs Alternative Science Debate: Analysis of Magnetic Resonance Imaging Research" *Economic and Political Weekly* (2006), 219-227; Prasad, Amit, "Scientific Culture in the 'Other' Theater of 'Modern Science': An Analysis of the Culture of Magnetic Resonance Imaging Research in India" *Social Studies of Science* vol.35 (2005), 463-489.

[67] For a list of Swedish hospitals' acquisitions of MRI devices until 1992, see SBU, *Magnetisk resonanstomografi* (Stockholm: SBU, 1992), p.86.

INTERLUDE: MRI:ZING HOMER SIMPSON

[1] Author unknown, *Homer Simpson Brain* http://www.simpsonstrivia.com.ar/wallpapers/homer-simpson-wallpaper-brain.htm, accessed on May 19, 2007.

[2] Cartwright, *Screening The Body* , p. 107.

[3] For instance, William Oldendorf writes the following in the introduction to his book about the development of brain imaging technologies, *The Quest for an Image of the Brain:* "We are inherently visual creatures, best suited to learn about the world around us through images—patterns of white, grays, blacks, and colors. Clinical medicine relies heavily on the visual sense to gather information necessary to diagnose disease. Visual inspection of the patient, instrumentation that extends the visual sense to see within the human body, and the creation within the physician's mind of a visual image of the hypothesized pathology are all part of diagnostic medicine." (Oldendorf, *The Quest for an Image of the Brain* , p.vii.)

[4] http://www.ariser.info/training/imgproc.php, accessed on May 19, 2007.

[5] Cartwright, *Screening The Body* , 107. Cf. also p.119: "At stake is the loss of the cultural text inscribed in the skin, the organs."

[6] On the establishment of the "cerebral body" in Western cultures, see Martensen, *The Brain Takes Shape* .

[7] Cf. also Cartwright, who notes that "the X-ray [...] has been a metaphorical site of major importance." (Cartwright, *Screening The Body* , p.107).

CHAPTER 2: UNDER THE CONTROL OF THE AUTHORITIES?

[1] Bertil Persson's CV: *En Strålande Historia / A Radiant Story, 06 NMR, March 2004*, Bertil Persson private archives.

[2] Interview with Bertil Persson.

[3] Ibid.

[4] Bertil Persson's CV.

[5] Bertil Persson, Personal communication; *NMR Imaging: Proceedings of an International Symposium on Nuclear Magnetic Resonance Imaging, October 1-3, 1981, Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, North Carolina,* 1981), e.g. p.243-246 (see also the program of the Symposium). Among the speakers were Damadian, Lauterbur and Mansfield. According to the first volume of the *Encyclopedia of nuclear magnetic resonance*, the Winston-Salem conference was an important moment in the development of NMR-imaging technology and research community. (Grant and Harris (eds.), *Encyclopedia of NMR* , p.120).

[6] Bertil Persson, Personal communication.

[7] Bertil Persson' notes: *From symposium in Winston-Salem Oct 1-3 1981*, Freddy Ståhlberg private archives / Department of Medical Radiation Physics, Lund University Hospital.

[8] Ibid. These puns on the abbreviation NMR were not uncommon in early MRI-scientist communities. Bettyann Holtzmann Kevles mentions for instance that "[b]efore NMR became MRI, chemists liked to say the letters stood for No More Radiologists." (Holtzmann Kevles, *Naked to the Bone* , p.245.)

[9] Interview with Lennart Wetterberg. On the same theme, see also Wahlund, Lars-Olof, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" in *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization,* Ingrid Agartz (Stockholm, 1992), p.I:4-I:5: "During recent years [i.e. 1980s], effective and lenient neurodiagnostic methods have been

introduced such as X ray computer tomography (CT) and magnetic resonance imaging (MRI). However these methods have not been widely used in the routine investigations of psychiatric patients. There are several reasons for this limitation and many CT units make strict medical priorities. The psychiatric patients may show diffuse somatic symptoms without focal neurological signs and the indication for neuroradiological investigations is thus usually considered to be low. Due to the long waiting time for examination, many psychiatrists do not refer their patients for CT or MRI."

[10] Wetterberg, Lennart (ed.) *Svenska studenter i Los Angeles: ett experiment för att internationalisera utbildningen i psykiatri [Swedish students in Los Angeles : an experiment in order to internationalize education in psychiatry]* (Stockholm: Psykiatriska kliniken, Karolinska institutet, 1979), p.176.

[11] Holtzmann Kevles, *Naked to the Bone* , p.148-151; Blume, *Insight and Industry* , p.159-160. See also Oldendorf, *The Quest for an Image of the Brain* .

[12] Interview with Lennart Wetterberg.

[13] Ibid.

[14] See e.g. Calltorp, Johan, *Prioritering och beslutsprocess i sjukvårdsfrågor: Några drag i de senaste decenniernas svenska hälsopolitik* (Uppsala: Uppsala universitet, 1989), p.60-68, 79.

[15] Letter from V. Holmqvist and Tord Domangård to Britt Wennerfors: *Uppgifter om magnetkamera inom västra förvaltningsområdet (Vd 721/82), 1982-10-20*, Lennart Wetterberg private archives, my translation.

[16] *Karolinska institutets fonder* (Stockholm: Broberg, 1981) (fund no. 155); Rennestedt, Birgit, "PS. Psykiatrins pansarkryssare" *Läkartidningen* vol.79 (1982), 952. For an example of the redefinition of the St. Göran's fund as oriented towards MRI, see Wetterberg, Lennart, *De första 30 åren: 1961-1991: Psykiatriska kliniken, S:t Görans sjukhus* ([Stockholm]: [Psykiatriska kliniken, S:t Görans sjukhus], 1991), p.8.

[17] Rennestedt, "PS. Psykiatrins pansarkryssare" . Quote excerpted from the Table of contents summary of the article.

[18] Ibid., my translation.

[19] Ibid., my translation.

[20] Interview with Anders Hemmingsson.

[21] Lindqvist, Kjell, "Ny metod för helkroppsundersökning: Kemisk analys och anatomiska bilder utan ingrepp och röntgenstrålning" *Läkartidningen* vol.77 (1980), 4278-4280; Blume, *Insight and Industry* , p.214.

[22] "The second [whole-body scanner] goes to Monterey in Mexico, who thanks to their oil have virtually unlimited resources for medical equipment." My translation. (Lindqvist, "Ny metod för helkroppsundersökning: Kemisk analys och anatomiska bilder utan ingrepp och röntgenstrålning" , p.4280.)

[23] Ibid., p.4280, my translation.

[24] Application no.17259 from Anders Hemmingsson et al. to MFR: *Nukleär magnetisk resonans (NMR) för helkroppsundersökningar in vivo (K83-174-6676-01), January 15, 1982*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital; Handwritten commentary on Uppsala University Hospital, Action plan about the constitution of an MRI group: *Handlingsplan, Undated document [probably autumn 1981]*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[25] Interview with Anders Hemmingsson.

[26] Handwritten commentary on "Uppsala University Hospital, Action plan about the constitution of an MRI group...".

[27] Hemmingsson's group contacted representatives from disciplines such as general medicine, urology, oncology, surgery, neurology, orthopedy, otorhinolaryngology ("Application no.17259 to MFR..."). The NMR project seems to have acquired legitimacy early in the Uppsala hospital management. This is suggested by the fact that an invitation was sent to SPRI (see below) by Herman Lodin, chief radiologist at UAS' diagnostic radiology department, together with Lennart Larsén, UAS's intendent and member of the hospital management board. (Letter by Herman Lodin and Lennart Larsén (UAS): *Invitation for a meeting with Spri, December 21, 1981*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.)

[28] Interview with Anders Hemmingsson. Hemmingsson also mentioned that he established contact with MP Arne Gadd (representative in the Swedish Parliament, *riksdagen*). Lobbying at the parliamentary level did not really make sense to me; in our interviews, Hemmingsson seemed not to remember why he had contacted Gadd in particular, except that he was from Uppsala and had a position in a goverment office. Later on, when going through archival material, I realized that Gadd was the chairman of FRN's committee for funding of costly research equipment (*Forskningsrådsnämndens delegation för finansiering av dyrbar utrustning,* FINDU) since at least 1980 (see for instance Minutes, FRN: *Sammanträdesprotokoll nr 31 FRN möte 1980-12-12,* Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:2, FRN). The applications sent to MFR or FRN that aimed at financing the purchase of costly research equipment were formally ranked by FINDU. Hemmingsson's contact with Gadd then made sense. When this contact took place is unknown to me, and, I believe, not of utmost importance (the crucial decisions about technology funding were not made by FINDU, cf. next section).

[29] This implied that expenses such as building costs and operation costs for MRI would have to be supported by the county. UAS was the last university hospital to change status, from government to county hospital, see e.g.: "Nytt avtal klart för UAS-läkarna vid övergången till landstinget" *Läkartidningen* vol.79 (1982), 4887.

[30] Interview with Anders Hemmingsson. A potential argument for Hemmingsson to work with them on MRI-technology development would have been to get funds from the National Board for Technical Development (*Styrelsen för teknisk utveckling,* STU). "Uppsala University Hospital, Action plan about the constitution of an MRI group...", handwritten commentary.

[31] Call from Lennart Larsén to UAS NMR group: *for a meeting with the director of Scanditronix in February 1982, December 23, 1981*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[32] "Letter by Herman Lodin and Lennart Larsén (UAS)...", my translation; emphasis added. SPRI was an authority with a responsibility for the efficiency of the *clinical* world on a national scale. They had no financial power, but had begun to promote the assessment of medical technologies in clinical practice, for example by organising a conference in November 1981. See e.g.: Carlsson, Yngve, "Spri-konferens om utvärdering av medicinsk teknologi: Nödrop från politiker till läkare: Hjälp oss att "få tandkrämen i tuben igen"!" *Läkartidningen* vol.78 (1981), 4421-4424.

[33] "Application no.17259 to MFR...".

[34] Blume, *Insight and Industry* .

[35] Two letters from Henry Danielsson and Ingwar Lennerfors (MFR): *Initiativ gemensamt MFR och RmC till utvärdering av nukleär magnetisk resonans (NMR) som medicinsk diagnostisk metod, Dnr 429/82,* May 3, 1982 and May 17, 1982, Diarieförd allmän korrespondens, E1:394, MFR; FRN, correspondence about MFR's priority proposal: *Sammanställningar av MFR:s pri[o]riteringar av ansökningar om dyrbar vetenskaplig utrustning; inkl följande brevväxling,* April 28, 1982, Diarieförd allmän korrespondens, E1:394, MFR; "[Offentliga underrättelser] Första NMR-utrustningen till Akademiska sjukhuset" *Läkartidningen* vol.79 (1982), 2673.

[36] Interview with Tore Scherstén.

[37] Ibid.; Interview with Håkan Eriksson; MFR Annual report 1981/1982: *Årsredogörelse 81/82*, 1982, Projektkataloger [Årsredogörelser], B3B:6, MFR; MFR Annual report 1980/1981: *Årsredogörelse 80/81*, 1982, Projektkataloger [Årsredogörelser], B3B:6, MFR; MFR Annual report 1979/1980: *Årsredogörelse 79/80*, 1981, Projektkataloger [Årsredogörelser], B3B:6, MFR.

[38] Minutes, FRN: *Sammanträdesprotokoll nr 34, FRN, sammanträdesdatum 1981-06-09*, Sammanträdesprotokoll, A1:2, FRN

[39] Interview with Håkan Eriksson; Calltorp, *"Prioritering och beslutsprocess i sjukvårdsfrågor"* .

[40] "MFR Annual report 1980/1981...", p.12,29; "MFR Annual report 1981/1982...", p.17-18,25; MFR Annual report 1982/1983: *Årsredogörelse 82/83*, 1983, Projektkataloger [Årsredogörelser], B3B:7, MFR, p.12,16.

[41] "MFR Annual report 1982/1983...", p.12,16,20. Quote p.12.

[42] Interview with Håkan Eriksson; Interview with Tore Scherstén.

[43] Interview with Tore Scherstén.

[44] Interview with Håkan Eriksson. Cf. also Interview with Tore Scherstén.

[45] The earliest letter I found in MFR's archive that relates to NMR imaging is from April 1982 (Letter from MFR to FRN: *Sammanställning av MFR:s prioriteringar av ansökningar om dyr vetenskaplig utrustning som överlämnats av FRN till MFR*, April 28, 1982, Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:15, FRN). A later document refers to a meeting on April 22 1982, where MFR's decision about an NMR initiative was taken: "Two letters from Henry Danielsson and Ingwar Lennerfors (MFR)...".

[46] Statement by MFR Priority committee for surgery and Tore Scherstén about Herman Lodin et al.'s application: *Yttrande över Herman Lodins ansökan KD2011: "Avbildande utrustning för human helkroppsundersökning med nukleär magnetisk resonans (NMR)"*, unknown date, Ansökningshandlingar, F1:992, MFR, my translation.

[47] Undated document: *List of applications (Spring 1982) registered by MFR*, Ansökningshandlingar, F1:1136, MFR; Undated document: *List of applications registered by MFR and corresponding funding decisions*, 1982, Ansökningshandlingar, F1:1136, MFR.

[48] "Application no.17259 to MFR..." (a copy of this application was also available in MFR's archive); Application sent by Bertil Persson to MFR (K322): *Utveckling av metoder för/och jämförande studier av non-invasiva blodflödesmätningar med mikrosfärer, inerta gaser, kolloider och kärnspinnsresonans (NMR)*, January 14, 1982, Ansökningshandlingar, F1:784, MFR; Minutes, MFR: *Beslutslista förd vid sammanträde med medicinska forskningsrådet torsdagen den 6 maj 1982, Dnr 350/82*, May 6, 1982, Rådets protokoll, A1A:24, MFR. Applications which do not get funded are discarded from MFR's archive; Walstam's application was therefore not archived there. The very sparse information I have found about it comes therefore from the few documents which mentioned it such as "decision lists" (*beslutslistor*) on funding of applications.

[49] See e.g. Minutes, FRN: *Sammanträdesprotokoll nr 38, FRN, sammanträdesdatum 1982-02-12*, Sammanträdesprotokoll, A1:2, FRN.

[50] Statement by MFR Priority committee for surgery and Tore Scherstén about Bertil Persson's application to MFR: *Yttrande över Bertil Perssons ansökan K0322 till MFR "Utveckling av metoder för/och jämförande studier av non-invasiva blodflödesmätningar med mikrosfärer, inerta gaser, kolloider och kärnspinnresonans (NMR)"*, 1982, Ansökningshandlingar, F1:992, MFR, my translation.

[51] Minutes: *Meeting on NMR, held at the library of the department of diagnostic radiology, Uppsala University Hospital, March 9, 1982*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital

[52] "Statement by MFR Priority committee about Herman Lodin et al.'s application…", my translation, emphasis added.

[53] "Minutes: Meeting on NMR, UAS, March 9,1982…", my translation.

[54] See e.g. Berggren, Ulf, *Datortomografins framväxt och spridning: en studie av en ny teknik ur ett organisations- och branschteoretiskt perspektiv* (Lund: Studentlitteratur, 1982); *Hälso- och sjukvård i internationellt perspektiv / Hälso- och sjukvård inför 90-talet (HS 90)*, SOU 1981:3, (Stockholm, 1981), 30. The diffusion of CT in Sweden in the 1970s was uncontrolled, but it was argued in 1981 that it had led to important financial savings. See Carlsson, "Spri-konferens om utvärdering av medicinsk teknologi: Nödrop från politiker till läkare: Hjälp oss att "få tandkrämen i tuben igen"!"

[55] See a partly similar comment in Blume, *Insight and Industry* , p.220.

[56] "Minutes: Meeting on NMR, UAS, March 9,1982…"

[57] Typewritten communication by Anders Hemmingsson to P.O. Lundberg: *Draft of Letter to Arne Gadd concerning NMR, Undated, [March-April 1982]*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital (my translation.)

[58] Interestingly enough, the final letter to Gadd, written and sent by P.O.Lundberg, chief of the neurology clinic, was much less political and more "technical" in the arguments it evoked to make Uppsala the only acceptable candidate for investment in MRI. Lundberg presented the MRI project as a clinical one, and turned potential cooperators, among them Scanditronix, into providers—thereby excluding political plans for development cooperation, which clearly reduced MRI to a clinical tool. The fact that neurology, a discipline expected to be strong MRI users in the continuity of CT, had been mobilized, reinforced the clinical face of MRI, as opposed to e.g. physical chemistry or radiation physics which stood for experimenters and potential developers of the technology.

[59] Should this redefinition be understood as irregular? Hemmingsson's formulation work may be interpreted as a "tuning in" of his project to MFR's vision. Which is not so strange, since MFR was the potential financier of most immediate importance, and Hemmingsson was one of the two candidates for the funding of an MRI-evaluation project. Neither was evaluation of technology as such an unusual practice in radiology. For instance, the first CT scanner purchased in Sweden was first used to assess the technology's clinical uses, on the initiative of the group of radiologists involved in that acquisition. (cf. Berggren, *Datortomografins framväxt och spridning* , p.147-148. An example of a large-scale comparative evaluation of CT in the 1970s at Serafimerlasarett in Stockholm is reported in Udén, Rolf, et al., "Serafenprojektet" *Läkartidningen* vol.77 (1980), 106-126). From the evidence I have been through, there is thus no reason to think that the contact between UAS and MFR did not follow the rules of the research funding game. In our interview, Håkan Eriksson commented on the way MFR's choice of research group took place that MFR had then as its role to take its own initiatives, and to choose rather freely the sites where initiative projects should be conducted was a normal way of so doing. He also added that what I have called the rules of the game were then different from today, and that were the selection of a research site for such a project to be done today, things would be conducted differently. Interview with Håkan Eriksson.

[60] Gieryn, Thomas F, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists" *American Sociological Review* vol.48 (1983), 781-795. Gieryn's contribution was to foreground boundaries (such as between "science" and "non-science") as the outcome of social processes (e.g. scientists' struggles for

authority and/or autonomy) rather than the result of some intrinsic character of e.g. scientific work.

[61] "Two letters from Henry Danielsson and Ingwar Lennerfors (MFR)…" My translation.

[62] Ibid.

[63] [Forskningsnämnden vid RmC], "[Meddelande] Forskning om NMR och hälsokontroller får anslag av Cancerfonden" *Läkartidningen* vol.79 (1982), 2176, my translation.

[64] List of applications for costly equipment, FRN: *Förteckning avseende ansökningar om medel för dyrbar utrustning 1982*, [January 5, 1983], Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:15, FRN; "Minutes, MFR, May 6, 1982…".

[65] Decision letter, from Henry Danielsson and Ingwar Lennerfors (MFR) to MFR members: *Per capsulambeslut ang placering av NMR-utrustning, Dnr 597/82,* June 15, 1982, Diarieförd allmän korrespondens, E1:395, MFR. The only justificative information in this document is quoted here (my translation): "In order to investigate the question of which research group the NMR equipment and resources for personnel and usage should be attributed to, the committee [MFR] appointed the vice-chairman, Professor Tore Scherstén, and myself, Danielsson. This inquiry was to be conducted together with two representatives of RmC, professors Bengt Gustafsson and Lars-Gunnar Larsson. The working group mentioned above had a meeting on June 14, 1982. During the meeting were discussed first, the applications received by MFR and RmC on January 19, 1982 (Professor Walstam et al., Karolinska Hospital; Associate Professor Hemmingsson and Professor Lodin, et al., [Uppsala] University Hospital); and second, the possibility of placing [the project] on other university sites. On the basis of an analysis of the applications' research programs and other considerations, the working group decided to propose that the resources be granted to Associate Professor Hemmingsson and Professor Lodin and co-workers, radiology department, University Hospital, Uppsala."

Walstam's group was not mentioned by other actors in my interviews, and Håkan Eriksson, when I asked him in our interview more than twenty years after the events at stake here, did not remember that Karolinska had put in an application at all:

Dussauge: "When Uppsala applied for funds in 1982, Karolinska also put in an application for MRI…

Eriksson: This is more than I know… My understanding is pretty much that MFR had identified Uppsala as the strongest part; that radiology, which had been strong at Karolinska wasn't that strong, but what KI [Karolinska Institute] or KS [Karolinska Hospital] were strong at, was PET—it wasn't NMR. So I don't even remember that we even had Karolinska as a discussion point."

Interview with Håkan Eriksson, my translation. Unfortunately, not enough can be known about the working group mentioned above. I was not able to locate the RmC representatives, and no document about or from this group could be found in MFR's archive. The death of Rune Walstam in 2002 sadly made it impossible for me to collect his own MRI history.

[66] Anders Hemmingsson's memo for NMR-hearing at UAS on September 16, 1983: *NMR i Uppsala, Undated [September 1983]*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[67] "[Offentliga underrättelser] Första NMR-utrustningen till Akademiska sjukhuset…" , my translation.

[68] MFR wrote explicitly that the evaluation of MRI would generate methodological guidelines for the purchase of costly medical technologies. Cf following quote from MFR's annual report (MFR Annual report 1983/1984: *Årsredogörelse 83/84,* 1984, Projektkataloger

[Årsredogörelser], B3B:7, MFR, p.11): "MFR estimates that the evaluation [of NMR imaging] will take a few years. After which basic data should exist for decision-making in the use of different advanced diagnostic methods in health care. The NMR initiative may thus be judged as of great importance for health care planning." My translation.

69 Letter from MFR to the Federation of County Councils (LF): *MFR, RmC och FRN beviljar sammanlagt 7 Mkr till utvärdering av NMR-teknik i klinisk diagnostik, Dnr 762/82*, 82-08-27, Diarieförd allmän korrespondens, E1:398, MFR; "Minutes, MFR, May 6, 1982...". Quote from "Two letters from Henry Danielsson and Ingwar Lennerfors (MFR)...", my translation.

70 See e.g. "Risk för investeringar - Landstingsförbundet vill vänta med NMR" *Läkartidningen* vol.79 (1982), 3770. Although LF's directive had no legal normative value (nobody was juridically forced to respect it), it was soon received as an authoritative moratorium, a decree—which, on the other hand, meant that hospitals might bypass it if they succeeded in finding other funding strategies; see for instance: Interview with Anders Hemmingsson; Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen.

71 "List of applications for costly equipment, FRN 1983..."

72 In an ironic turn, the government decided to devalue the Swedish crown by 17% between 1982 and 1983. UAS needed to apply in June 1983 for an additional compensatory grant of more than one million crowns, which they got in December 1983. (Interview with Anders Hemmingsson; Letter from Hans Landberg and Olle Thylander (FRN) to Anders Hemmingsson and UUH: *Regarding NMR equipment (superconducting)*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital) .

Within UAS, the MRI group worked on convincing the hospital management to fund the installation of the device and related construction work, since MFR/FRN had made clear that their grant may not be used for such a purpose. In October 1982, the hospital management consented formally to support the installation of the NMR scanner and the necessary construction work. (Lennart Larsén's notes: *Chronology of the estimates of construction and installation costs related to the MRI project, February 1, 1984*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital; Minutes: *Protokoll 207, Nuclear magnetic resonance (NMR), Dnr 0201-0510-81, October 10, 1982*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.)

However, the hospital management needed, in turn, to convince the county council to participate in the extra funding of the project. This would require new estimates on the basis of better understanding the requirements for the space where the device was to be placed, and its infrastructure. Those estimates had to be re-calculated in August 1983 after the decision had been made to purchase supraconducting equipment, whose magnet imposed new, costly requirements concerning the cooling system. As a result, it was not until September 1983 that the Uppsala County Council made the hasty decision to support the project with one million to cover contruction/installation costs and half a million for operation of the MRI device during the first year. Interestingly enough, the county council intended to involve *Landstingsförbundet* in the current phase, arguing that "*landstingsförbundet* has given other county councils the recommendation not to purchase NMR equipment pending the assessment at Uppsala University Hospital. With respect to this, *landstingsförbundet* ought perhaps to examine the possibility of supporting financially the now ongoing research projects" (my translation). The allocated sum would be revised in 1984. ("Lennart Larsén's notes: Chronology of the estimates...".)

The formal decisions from MFR and FRN, to be approved by the government, took half a year, and in January 1983 the last approval was obtained. UAS would be getting five million crowns from FRN to pruchase an MRI scanner, one million from RmC and one from MFR to conduct research (Letter from Olle Thylander (FRN),*February 1, 1983*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital).

[73] Minutes: *Meeting of the UAS NMR-group held on August 17, 1982, 1982*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital; Anders Hemmingsson's memo: *Concerning NMR, August 17, 1982*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[74] "Anders Hemmingsson's memo: Concerning NMR…", my translation.

[75] From autumn 1982, the purchase process was officially under the coordination of a national institution, the Committee for the Equipment of Universities and Colleges (*Utrustningsnämnden för universitet och högskolor*, UUH), who was responsible to the research councils for conducting an assessment of the market possibilities and prices, and producing tenders in cooperation with UAS' MRI group, who were to specify their requirements regarding the device to be purchased. ("Anders Hemmingsson's memo for NMR-hearing at UAS on September 16, 1983…").

The official rules for purchase were strict: UAS was to provide UUH with a "neutral technical requirement specification", and UAS was forbidden to undertake a purchase by themselves. On the other hand, they were expected to contribute with information on potential providers. (Letter from UUH to UAS: *concerning the purchase of an NMR equipment, February 14, 1983*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.)

Practically speaking, the idea of a "neutral technical requirement specification" was necessarily blurry. The requirements were defined from the available knowledge of the available technical possibilities; and as other factors could play a role in Hemmingsson's choice of a provider, the specification was most likely to be written after an informal, implicitly tentative decision—which is what did happen. Philips, Siemens and General Electrics were the foremost candidates; but other companies were also discussed. During the autumn of 1982, the UAS MRI group visited Picker, Siemens, Philips, Bruker, Diasonics, Technicare, Fonar and M&D Technology Ltd. The criteria for choice were of different characters: performance was defined among others in terms of partial versus whole-body scanner, examination time, image resolution, and very much dependent on the magnet type and strength. Other factors were involved concerning the kind of contact with the provider. European companies offered a singular advantage as they were located closer and offered more continuous contact. (Interview with Anders Hemmingsson; Application no.19001 from Anders Hemmingsson et al. to MFR: *Nukleär magnetisk resonans (NMR) för helkroppsundersökningar in vivo (K84-174-6676-02A), January 14, 1983*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital).

A paradoxical situation was that during this period of investigation and choice for UAS, providers were entering the market or producing prototypes expected to stand ready a year later; available technical possibilities evolved also. In other words, and with the knowledge that a purchasing process may take between one or two years, it was difficult to take anything for granted for longer than a couple of months, and difficult to make a decision.

Siemens would be the winner of the selection process. Hemmingsson's original intention was to purchase a device based on a superconducting magnet, which allowed stronger and more stable magnetic fields, but turned out to cost more than the funds granted by FRN. Consequently, the UAS MRI group produced a first call for tenders in February 1983, that concerned a financially more realistic alternative, i.e. a device functioning with a permanent magnet. But thereafter, UAS' MRI group contacted Siemens about their tender. Siemens, who did not have any permanent magnet device, came after negotiation to offer a supraconducting device for the price of a permanent one. At that point, UAS' decision was made. Two months after the first call for tenders, UAS' MRI group replaced it with a new one, this time on superconducting equipment. The reasons Hemmingsson gave officially, though, are that there were first problems of availability, safety and location of superconducting equipment, which were later overcome by the possibility of a better, superconducting equipment that it suddenly seemed possible to purchase... In other words: The latter technical argument made it possible to render Hemmingsson's change of perspective neutral, and at the same time position UAS at the forefront of the growing techno-medical field of MRI. In September 1983, UAS was conducting final negociations with Siemens and UUH that resulted in a preliminary contract. ("Anders Hemmingsson's memo for NMR-hearing at UAS on September 16, 1983..."; Interview with Anders Hemmingsson; Letter from Uno Erikson (UAS) to Per Erik Danielsson (UUH): *including draft for contract with Siemens signed by their representative P.Grassman, September 13, 1983*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.)

[76] "Anders Hemmingsson's memo for NMR-hearing at UAS on September 16, 1983..."

[77] Ibid.; Bo Jung's memo: *Memo for "NMR i Uppsala" (hearing held at UAS September 16, 1983), September 15, 1983*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[78] Bo Jung, MRI project plan: *detailed phases, Undated [fall 1983]*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital; "Minutes: Meeting on NMR, UAS, March 9,1982..."; Interview with Anders Ericsson

[79] Anders Hemmingsson, Project description in English to MFR: *March 7, 1984*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[80] Winge, Sören, "Stora kameralyftet på Akademiska sjukhus", *Uppsala Nya Tidning*, August 29, 1984.

[81] *Landstingsförbundet*'s modified recommendation was formulated as a continuity ("[the 1982 recommendation] was complemented") aimed at rational organisation and development of health care—in contrast to other versions of the story which describe the early 1982 recommendation as a moratorium which could not be kept and had to be replaced with a more flexible attitude in 1984. Håkan Eriksson also explained to me that LF's original idea was to have something like a ban on NMR during the evaluation time, but that MRI's quick technological development (and, I would add, commercialization) led many hospitals to purchase their own MRI scanner before the evaluation was completed. See "Risk för investeringar - Landstingsförbundet vill vänta med NMR..." ; "Landstingsförbundet och MR-tekniken: "Mjukare" rekommendation accepterar fler enheter" *Läkartidningen* vol.81 (1984), 3884; Recommendation AC 84:43 from the Federation of County Councils (Landstingsförbundet): *Komplettering av rekommendation (AC 45/82) - investeringar i NMR och datortomografer, 1984*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital; Spri, *MRT - Magnetisk resonanstomografi* (Stockholm: Spri, 1986), p.3; Interview with Håkan Eriksson.

[82] Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen.

[83] Interview with Bo Nordell; Brochures and tenders: *from MRI-manufacturers to Karolinska Hospital, 1984-1985*, Bo Nordell private archive / MR-center, Karolinska Hospital.

[84] Spri, *MRT* , p.6; SBU, *Magnetisk resonanstomografi* , p.86.

[85] Spri, *MRT* , p.62-63; Wetterberg, Lennart, "Vad kan vi vänta oss av 'magnetkameran'?" *Läkartidningen* vol.81 (1984), 2659-2660.

Wetterberg's group would reiterate this vision and argument in 1989, in Wahlund, Lars-Olof, et al., "Magnetisk resonanstomografi inom psykiatrin - sjukvårdsmässiga vinsterna uppenbara" *Läkartidningen* vol.86 (1989), 3991-3994. Hemmingsson's argumentation was also explicit in two TV programs broadcast in 1984: *Sjukhusmagneten*. TV2, October 10, 1984; 21.00-21.35; *Hälsomaskinen*. TV2, October 15, 1984; 20.00-20.35. For the context of these debates, see Dussauge, Isabelle, "Questioning Medical Technology: The Discourse on Technology in *Läkartidningen* 1978-1985" *Polhem 2004* vol.1 (2005), 65-89.

[86] Wetterberg, "Vad kan vi vänta oss av 'magnetkameran'?..."

[87] "FRN, correspondence about MFR's priority proposal, 1982..."; "Magnetisk resonanstomografi stor investering. Ännu inte helt färdig för klinisk bruk" *Läkartidningen* vol.84 (1987), 3944-3945; specifically about the diffusion of MRI in the USA: Spri, *MRT* , p.6,11,28.

[88] Whereas Sankt Göran and Umeå had purchased low-field scanners (0.02T), Lund had a combined permanent/resistive device (0.3T), and UAS and KS supraconducting equipments (0.5T) in 1986, according to an article published by radiologists Anders Hemmingsson and Holger Pettersson (Hemmingsson, Anders and Holger Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" *Läkartidningen* vol.84 (1987), 1527-1529).

[89] Spri, *MRT* , p.7.

[90] See e.g. Sepponen, Raimo E, "Low-Field MR Imaging - Development in Finland" *Acta Radiologica* vol.37 (1996), 446-454, p.447; Spri, *MRT* , p.129; Boijsen, Erik and Bertil Persson, "Skelettartefakter och genetiska effekter undviks med kärspinnsresonanstekniken (NMR)" *Läkartidningen* vol.81 (1984), 2688-2692, p.2692; Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1527.

[91] Interview with Bertil Persson. See similar arguments in Sepponen, "Low-Field MR Imaging - Development in Finland" , which further refers to Sepponen's work on low-field MRI in the 1980s.

[92] Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" .

[93] See e.g. "Magnetisk resonanstomografi stor investering. Ännu inte helt färdig för klinisk bruk" ; Boijsen and Persson, "Skelettartefakter och genetiska effekter undviks med kärspinnsresonanstekniken (NMR)" , p.2692; Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1527.

[94] A general picture emerges from an analysis of the distribution of MRI articles in Acta Radiologica (the Nordic Journal of Radiology, dominated by Swedish publications and with its editorial committee in Sweden in the 1980s) between 1983 and 1990. Whereas just a few publications dealt with MRI in the mid-eighties (7 in 1985, 10 in 1986), no less than 19 to 25 articles per year were published about MRI or that dealt with MRI between 1987 and 1990, distributed across increasingly more diagnostic fields, i.e. roughly, organ categories. This increase still holds—although somehow less strikingly—when normalizing the number of MRI-related publications with *Acta Radiologica*'s total number of publications each year. The percentage of MRI-related publications compared to the total number of publications was the following: 2.2% in 1984, 5.8% in 1985, 8% in 1986, 15.8% in 1987, 8.3% in 1988, 18.7% in 1989, 16% in 1990—which can be contrasted to later figures: around 25% in the first half of the 1990s, 35% in the second half, over 40% in the early 2000s.

[95] MRI had entered the annual, national medical congress *Svenska Läkaresällskapets Riksstämma* rather shyly in 1981 and 1983, with two guest interventions about the possibility of whole-body imaging with MRI—of which one was by John Mallard. In 1983, it was Bertil Persson's turn to conduct the only symposium on MRI entitled "NMR in the service of medicine?", with contributions by himself, Erik Boijsen (Lund) and Bo Nordell (Karolinska Hospital) and the engineer Peter Killander. The topics were medically general and

sometimes technology-specific, e.g.: "NMR and its relationship to diagnostic radiology", "Examples of NMR examinations conducted with devices between 0.15-1-5T", "Medical applications of P-31 NMR spectroscopy". ("[Läkaresällskapets riksstämma 1981: Program / Svensk förening för medicinsk radiologi och Svensk förening för radiofysik]" *Läkartidningen* vol.78 (1981), 3935-3936; "[Läkaresällskapets Riksstämma 1983]" *Läkartidningen* vol.80 (1983), 4160-4198, p.4164.)

These first isolated interventions about NMR imaging contrast strongly with the *Riksstämma* 1984 and its two posters and ten paper presentations of which seven were dedicated to a specific thematic symposium called "MRI (magnetic resonance)", and in which many of the contributors were Swedish researchers (among others: Sten Cronqvist, Elisabet Englund, Elna-Marie Larsson, Bertil Persson, Ulf Tylén, Hans Ringertz, Holger Pettersson, Lars Malmgren, Freddy Ståhlberg, Leif Salford.) Most of this attention paid to MRI fell under the section for medical radiology, and was dedicated to a specific body part or medical purpose of MRI examination: examination of the vascular system, pelvis, musculo-skeletal tumors. The section for radiation physics had own interventions discussing experimental and technical questions, linked to the understanding of physical processes and image construction. This contrast in how radiology and radiation physics as medical fields formulated MRI-related topics was constant over the years 1984-1990: In diagnostic radiology, the determining research questions were medical and included technology, sometimes as a black box; whereas in radiation physics, the research questions concerned the nature of the MRI-induced phenomena in order to understand and analyze the pictures produced with MRI. Researchers from the two professions participated in each other's research presentations; in other words, the professional borders seem to have been rather permeable in this period of establishment of the technology. Nevertheless, at the *Riksstämma*, the major radiophysicists tended to regroup within their field after the first years. Within medical radiology, the issues were mostly clinical and evolved from the use of MRI in radiology, neuroradiology or psychiatry in general, through strong emphasis on the brain and central nervous system including tumors and epilepsy (1984-1988), towards more specific topics such as epilepsy investigations, dementia, contrast agents, pre-operative examinations of lung cancer, follow-up of heart surgery, pelvis tumors, or joint damage (1987-1990). These topics were thus most often specific to either a clinical issue or, more rarely, to the use of a certain kind of technology (e.g. low-field MRI). The section for neuroradiology/ neurosciences soon accounted for many of the presentations of MRI research, and other medical sections such as urology or pediatrics came to offer MRI presentations in their program. See: "[Läkaresällskapets Riksstämma 1984 - Sektionsprogram]" *Läkartidningen* vol.81 (1984), 4051-4087; "[Läkaresällskapets 82:e Riksstämma]" *Läkartidningen* vol.82 (1985), 3797-3839; "[Läkaresällskapets Riksstämma 1986]" *Läkartidningen* vol.83 (1986), 3704-; "[Läkaresällskapets Riksstämma 1987]" *Läkartidningen* vol.84 (1987), 3606-3654; "[Läkaresällskapets Riksstämma 1988]" *Läkartidningen* vol.85 (1988), 3695-3736; "[Läkaresällskapets Riksstämma 1989]" *Läkartidningen* vol.86 (1989), ; "[Läkaresällskapets Riksstämma 1990]" *Läkartidningen* vol.87 (1990), 3635-3681.).

[96] Cf. e.g. SBU, *Magnetisk resonanstomografi* .

[97] Spri, *MRT* ; Spri, *Magnetisk resonanstomografi i Norden* (Stockholm: Spri, 1987); SBU, *Magnetisk resonanstomografi* .

[98] About the transparent body and the utopia of corporeal transparency, see van Dijck, *The Transparent Body* .

[99] Hellgren, Lilian, "Alla magnetkameror är inte dyrbara": *Östgöta Correspondenten, March 27, 1985*, Lennart Wetterberg private archives, my translation.

INTERLUDE: MRI METAPHORS OF DISPLAY

[1] Searches performed on www.google.se on November 6, 2007, restricted to Swedish web pages. First search performed with: magnetkamera OR ”MR-kamera”; second search: magnetröntgen OR ”magnet röntgen”.

[2] See e.g. Jülich, *Skuggor av sanning* ; Reiser, Stanley Joel, "The science of diagnosis: medicine and the five senses" in *Companion Encyclopedia of the History of Medicine,* eds. WF Bynum and Roy Porter (London; New York: Routledge, 1993).

[3] About X-ray films, see Cartwright, *Screening The Body* .

[4] Svendgaard, Niels-Aage, "Magnetkameran ser mer än kirurgen" *Läkartidningen* vol.94 (1997), 1978-1979; Levine, Deborah, et al., "Fetal anatomy revealed with fast MR sequences" *American Journal of Roentgenology* vol.167 (1996), 905-908. For similar examples, with a somehow different interpretation, see Joyce, "Appealing Images" Where I stress the logics of display, which in turn reinforces discourses of representation vs reality, Joyce emphasizes that the use of "revealing" or "unveiling" tropes conflates the MR image with the body it displays (constructs). In both cases, the technological and human intervention at stake in creating MRI representations/bodies is rendered transparent (or erased, in Joyce's words).

[5] A few excerpts from Foucault's *Naissance de la Clinique* examplify this point: ”l'oreille et la main ne sont que des organes provisoires de remplacement en attendant que la mort rende à la vérité la présence lumineuse du visible; il s'agit d'un repérage dans la *vie*, c'est-à-dire dans la *nuit*, pour indiquer ce que seraient les choses dans la clarté blanche de la mort.” (Foucault, *Naissance de la clinique* , p.169, emphasis in original); ”La maladie, autopsie dans la nuit du corps” (p.132); ”Si bien que *découvrir* ne sera plus *lire* [...] une cohérence essentielle, mais pousser un peu plus loin la ligne d'écume du langage, la faire mordre sur cette région de sable qui est encore ouverte à la clarté de la perception, mais ne l'est plus déjà à la parole familière. Introduire le langage dans cette pénombre où le regard n'a plus de mots.” (p.173, emphasis in original.)

For the ”opaque depth” of the inner body and peering into the body as a journey from light to darkness, see Sawchuk, Kim, "Biotourism, Fantastic Voyage, and Sublime Inner Space" in *Wild Science: Reading feminism, medicine and the media,* eds. Janine Marchessault and Kim Sawchuk (New York: Routledge, 2000), and Stafford, Barbara Maria, *Body Criticism: Imaging the Unseen in Enlightment Art and Medicine* (Cambridge, MA: MIT Press, 1991) to whom Sawchuk also refers.

[6] Langone, John, "Nya scanners ser rakt igenom de gamla egyptierna" *Illustrerad Vetenskap* (1986), 68-71; "Medicinsk scanner daterar helgonfigurer" *Illustrerad Vetenskap* (1990), 25; "Ny teknik känner mumierna på pulsen" *Illustrerad Vetenskap* (1993), 19; "Avancerad scanner ger oss ny kunskap om flickoffer" *Illustrerad Vetenskap* (1997), 24.

[7] The scientific examples used here are based on Notman, Derek NH, et al., "Modern Imaging and Endoscopic Biopsy Techniques in Egyptian Mummies" *American Journal of Roentgenology* vol.146 (1986), 93-96.

[8] Ibid., 94.

[9] Successful technologies, applied to other mummies, were CT and endoscopy (the insertion of a small camera and micro-devices into the mummy's body to take tissue samples for analysis).

[10] For a cultural analysis of endoscopy, see van Dijck, *The Transparent Body* , p.64-82.

[11] Quote from Foucault, *Naissance de la clinique* , p.169.

CHAPTER 3: GOING RADIOLOGICAL

[1] Spri, *MRT* ; Spri, *Magnetisk resonanstomografi i Norden* .

[2] Läkartidningen's following scientific articles were published about MRI: Bergström, Kjell, et al., "Kärnspinnsresonans (NMR) - ny diagnostisk bildprincip med stora möjligheter" *Läkartidningen* vol.79 (1982), 4665-4667; Rennestedt, "PS. Psykiatrins pansarkryssare" ; Bergström, Kjell, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" *Läkartidningen* vol.81 (1984), 2683-2687; Boijsen, Erik and Bertil Persson, "Skelettartefakter och genetiska effekter undviks med kärnspinnresonanstekniken (NMR)" *Läkartidningen* vol.81 (1984), 2688-2692; Lindberg, Bo and Staffan Meurling, "NMR och PET - speciellt lämpliga metoder för pediatrisk diagnostik" *Läkartidningen* vol.81 (1984), 2668-2669; Wetterberg, Lennart, "Medicinsk kommentar - Vad kan vi vänta oss av "magnetkameran"?" *Läkartidningen* vol.81 (1984), 2659-2660; Agartz, Ingrid, et al., "Goda erfarenheter av nyinstallerad lågfältsmagnetkamera" *Läkartidningen* vol.82 (1985), 4116-4121; Bergström, Kjell, et al., "Magnetisk resonanstomografi fyller luckor inom radiologisk diagnostik" *Läkartidningen* vol.82 (1985), 4101-4106; Laurin, Sven, "Undersökning av barn med kärnspinnresonans (MRI)" *Läkartidningen* vol.82 (1985), 4112-4114; Pettersson, Holger, "Undersökning av muskuloskelettala systemet med kärnspinnresonans (MRI)" *Läkartidningen* vol.82 (1985), 4108-4111; "Angiografi med MRT blir smärtfri" *Läkartidningen* vol.84 (1987), 1871; Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" ; Holtås, Stig, et al., "Magnetresonanstomografisk undersökning av ryggen - en billig och säker diagnostisk metod" *Läkartidningen* vol.84 (1987), 1544-1547.

Other articles informed about MRI's diffusion and the authorities' control over it or discussed it: "[Offentliga underrättelser] Första NMR-utrustningen till Akademiska sjukhuset..." ; "Risk för investeringar - Landstingsförbundet vill vänta med NMR..." ; [Forskningsnämnden vid RmC], "Forskning om NMR och hälsokontroller får anslag av Cancerfonden" ; "[Meddelande] Donation på 4 milj till "magnetkamera" vid S:t Göran" *Läkartidningen* vol.81 (1984), 2716; "Landstingsförbundet och MR-tekniken: "Mjukare" rekommandation accepterar fler enheter" *Läkartidningen* vol.81 (1984), 3884; "Magnetisk resonanstomografi stor investering. Ännu inte helt färdig för klinisk bruk" .

[3] Blume, *Insight and Industry* , p.220.

[4] Spri, *MRT* ; Lars-Olof Wahlund, Personal communication.

[5] Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" ; Boijsen and Persson, "Skelettartefakter och genetiska effekter..." ; Pettersson, "Undersökning av muskuloskelettala systemet med kärnspinnresonans (MRI)" ; Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" ; Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" ; Holtås, et al., "Magnetresonanstomografisk undersökning av ryggen..."

[6] Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" , p.2683, my translation.

[7] Cf. historian of medicine Eva Åhrén's comment on the visual culture of anatomy: "What is not visible does not exist" ("Syns det inte så finns det inte"). Åhrén Snickare, Eva, *Döden, kroppen och moderniteten* (Stockholm: Carlsson, 2002), p.100.

[8] Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4113, my translation.

[9] Spri, *MRT* , p.28, my translation.

[10] For instance, radiologists Laurin, Pettersson and Williams wrote, about the use of MRI in examination of children, that "[m]alignant tumors, malformations [...] etc are easily observed [...] as well as the anatomy in [specific pathologies of the spine]". Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4112-4113, my translation.

[11] Ibid., p.4114, my translation.

[12] Spri, *MRT* p.60. See also p.61.

[13] Holtås, et al., "Magnetresonanstomografisk undersökning av ryggen..." , p.1545, my translation.

[14] Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1528, my translation.

[15] Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" , p.2684, my translation; Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4114. See also Pettersson, "Undersökning av muskuloskelettala systemet med kärnspinnresonans (MRI)" , p.4108: "The available reports are positive about MRI's usefulness in defining tumors." Cf. also the argumentation in the SPRI report that when compared to CT and PET in the diagnosis of hypophysis tumors, MRI "often delimits the tumors best". (Spri, *MRT* , p.62, my translation). See also p.62, about diagnosis of "small tumors on the auditive nerve".

[16] Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4112, my translation.

[17] That pathological anatomy's gaze was clinically oriented, i.e. it judged a representation's performance on its diagnostic power—MRI was for instance assessed to make it possible to "better diagnose alterations that were earlier difficult to judge", Spri, *MRT* , p.60, my translation.

[18] Cf. Boijsen and Persson, "Skelettartefakter och genetiska effekter..." ; Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" ; Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" ; Spri, *MRT* p.62; Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" ; Holtås, et al., "Magnetresonanstomografisk undersökning av ryggen..." , p.1547; "Angiografi med MRT blir smärtfri" .

[19] Cf. Boijsen and Persson, "Skelettartefakter och genetiska effekter..." ; Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4112; Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" , p.2683, 2685; Spri, *MRT* , p.61.

[20] The argument that MRI could image any plane can be found for instance in Bergström, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" , p.2683, 2684.; Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4113; Spri, *MRT* , p.61.

[21] This is not to say that MRI was perceived as free from the limitations of bodily materiality and geometry. Claustrophobic patients and children may need to be sedated (and indeed, often were). Although images in any plane could be obtained, the MRI scan produced for a diagnostic purpose was also influenced by the patient's position and stillness. These arguments acted as a reminder that the MRI images obtained were fundamentally entwined with a material and clinical situation—where the patient or volunteer's body was pushed into the scanner, its protons activated by magnetic fields, gradients and radio waves, and its magnetic reaction registered by the machine again.

[22] About the symbolics of reaching deeper into the body with technological means, see historian of medicine Ulrika Nilsson's comment on gynecologists' new forms of interventions in Nilsson, Ulrika, *Det heta könet: Gynekologin i Sverige kring förra sekelskiftet* (Stockholm: Wahlström & Widstrand, 2005), p.118-120.

[23] Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" ; Bergström, et al., "Kärnspinnsresonans (NMR) - ny diagnostisk bildprincip med stora möjligheter" .

[24] Bergström, et al., "Kärnspinnsresonans (NMR) - ny diagnostisk bildprincip med stora möjligheter" , p.4665, my translation. See also the following examples: Karlsson, Yngve, "Ny

teknik spränger radiologins gränser" *Läkartidningen* vol.80 (1983), 1331-1334; Boijsen and Persson, "Skelettartefakter och genetiska effekter..." , p.2692.

[25] Bergström, et al., "Kärnspinnsresonans (NMR) - ny diagnostisk bildprincip med stora möjligheter" , p.4666, my translation. See also: Cederblom, Staffan, "Radiologins möjligheter vid vanliga kliniska symtom" *Läkartidningen* vol.81 (1984), 2358-2362, p.2362.

[26] Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4113, my translation.

[27] Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1527, my translation.

[28] Pettersson, "Undersökning av muskuloskelettala systemet med kärnspinnresonans (MRI)" p.4108, my translation.

[29] Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1529, my translation. Similarly, see Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1529.

The Uppsala radiologists singled out the bodily microdynamic of water—especially exchanges between intra- and extracellular spaces—as one source of problems in tissue characterization, see Bergström, et al., "Magnetisk resonanstomografi fyller luckor inom radiologisk diagnostik" , p.4101.

[30] Laurin, "Undersökning av barn med kärnspinnresonans (MRI)" , p.4114, my translation.

[31] Cf. also:

- SPRI's evaluation report in 1986: "Moreover, the method [MRI] can give information about cell-chemical, physiological and metabolic states and processes. The potential for research and development is therefore great." (Spri, *MRT* p.28)

- Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1529: "MRI is already a clinically established method for the examination of several organs. [---] Moreover, magnetic resonance will have an important place in research on the properties of different tissues in the future. This will take the form of studies of hydrogen and of other naturally occurring nuclei in normal and pathological tissue" (my translation.)

In 1987, magnetic resonance spectroscopy in vivo was described as "so far almost only experimental" but "opening new interesting possibilities for medical diagnosis", see "Magnetisk resonanstomografi stor investering. Ännu inte helt färdig för klinisk bruk" .

[32] Spri, *MRT* , p.62, my translation.

[33] I.e. in the evaluation report. For example, groups like Bertil Persson's in Lund were given space to write about MRI in the evaluation report – but Persson's chapter was not about what kind of information NMR conveyed or what should be done with the technology; it was confined to discussing the effects on the body of the radiations involved in NMR.

[34] For contemporary and more detailed technical information about MRI coils (and a few pictures showing what coils can look like), see Chapter 9 in the following hypertext book: Hornak, Joseph P, *The Basics of MRI* http://www.cis.rit.edu/htbooks/mri/ (Accessed on March 1, 2007).

[35] Cf. e.g. Hemmingsson and Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" , p.1527.

[36] Larsson, E-M, et al., "Coil selection for magnetic resonance imaging of the cervical and thoracic spine using a vertical magnetic field" *Acta Radiologica* vol.30 (1989), 141-146. This article was also part of Larsson's dissertation: Larsson, E-M, *Magnetic Resonance Imaging of the Cervical and Thoracic Spine and the Spinal Cord: A study using a 0.3 T vertical magnetic field* (Diss.; Lund, 1989).

[37] Larsson, E-M et al., "Coil selection for MR imaging…" in Larsson, *MRI of the Cervical and Thoracic Spine and the Spinal Cord* , p.16

[38] Ibid., p.18.

[39] Larsson, et al., "Coil selection for MRI of the cervical and thoracic spine..." ; Larsson, *MRI of the Cervical and Thoracic Spine and the Spinal Cord* .

[40] Larsson, et al., "Coil selection for MRI of the cervical and thoracic spine..." ; Larsson, *MRI of the Cervical and Thoracic Spine and the Spinal Cord* .

[41] Prasad, "Making Images/Making Bodies" .

[42] Foucault, *Birth of the Clinic* , p.126, 135-136, 139-140, 162-163.

[43] Larsson, E-M, et al., "Emergency magnetic resonance examination of patients with spinal cord symptoms" *Acta Radiologica* vol.29 (1988), 69-75, p.69. Larsson and colleagues also write: "In some cases, the nature of the lesion can be inferred from specific [MR] signal characteristics [...]. *In most instances, however, the diagnosis is made from the findings at MR examination taking the clinical picture into account.*" Larsson, et al., "Emergency magnetic resonance examination of patients with spinal cord symptoms" , p.74-75, emphasis added.

[44] Larsson, et al., "Emergency magnetic resonance examination of patients with spinal cord symptoms"

[45] Ibid.

[46] Prasad, "Making Images/Making Bodies" .

[47] I will come back to the fundamental issue of *how* different kinds of data could be compared and with which impact on the formation of the MRI gaze in Chapter 6.

[48] Larsson, et al., "Emergency magnetic resonance examination of patients with spinal cord symptoms" , p.71.

[49] Foucault, *Naissance de la clinique* . The idea that the development of contemporary imaging technologies may be read as the recapitulation of earlier medical history is inspired by Waldby, *The Visible Human Project: Informatic Bodies and Posthuman Medicine* , p.51-80. Waldby contends in turn that this is by no means specific to the technomedical project she studies—or to any technology—but that it "could be argued that all technologies are also histories of technology". Waldby, *The Visible Human Project: Informatic Bodies and Posthuman Medicine* , p.164 note 1.

[50] Hemmingsson, A., et al., "Structure Enhancement by Subtraction in Magnetic Resonance Imaging" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 459-461; Thuomas, KÅ, et al., "Subtraction in magnetic resonance imaging" *Acta Radiologica. Supplementum* vol.369 (1986), 483-485; Tovi, M, et al., "Tumour delineation with magnetic resonance imaging in gliomas. A comparison with positron emission tomography and computed tomography" *Acta Radiologica. Supplementum* vol.369 (1986), 161-163; Thuomas, Karl-Åke, *Aspects of Image Intensity and Relaxation Time Assessment in Magnetic Resonance Imaging: An experimental and clinical study* (Diss.; Uppsala, 1987).

[51] Thuomas, *Aspects of Image Intensity and Relaxation Time Assessment in Magnetic Resonance Imaging: An experimental and clinical study* , p.33.

[52] Hemmingsson, et al., "Structure Enhancement by Subtraction in Magnetic Resonance Imaging" , p.459.

[53] For instance, Tovi et al. refer to Brant-Zawadzki, Badami, Mills, Norman and Newton: "Primary intracranial tumor imaging. A comparison of magnetic resonance and CT." *Radiology* vol.150 (1984):435. Tovi, M, et al., "Delineation of gliomas with magnetic resonance imaging using Gd-DTPA in comparison with computed tomography and positron emission tomography" *Acta Radiologica* vol.31 (1990), 417-429

[54] Hemmingsson, A., et al., "Relaxation Enhancement of the Dog Liver and Spleen by Biodegradable Superparamagnetic Particles in Proton Magnetic Resonance Imaging" *Acta Radiologica* vol.28 (1987), 703-705; Thuomas, *Aspects of Image Intensity and Relaxation Time Assessment in Magnetic Resonance Imaging: An experimental and clinical study* ; Lönnemark, M., et al., "Superparamagnetic Particles as an MRI Contrast Agent for the Gastrointestinal-Tract" *Acta Radiologica* vol.29 (1988), 599-602; Hemmingsson, A., et al., "MR-Cholangiography with a Double Contrast Technique" *Acta Radiologica* vol.30 (1989), 29-33; Lönnemark, M., et al., "Effect of superparamagnetic particles as oral contrast medium at magnetic resonance imaging - A phase I clinical study" *Acta Radiologica* vol.30 (1989), 193-196; Tovi, et al., "Delineation of gliomas with magnetic resonance imaging using Gd-DTPA in comparison with computed tomography and positron emission tomography" ; Wikström, M., et al., "Magnetic resonance imaging of acute myocardial infarction in pigs using Gd-DTPA" *Acta Radiologica* vol.31 (1990), 619-624.

Selected publications by other Swedish research groups about contrast agents in MRI: Holtås, S, et al., "Signal alterations, artifacts and image distortion induced by a superparamagnetic contrast medium" *Acta Radiologica* vol.31 (1990), 213-216; Herrlin, K, et al., "Gadolinium-DTPA enhancement of soft tissue tumors in magnetic resonance imaging" *Acta Radiologica* vol.31 (1990), 233-; Olsson, Magnus BE, et al., "Ferromagnetic particles as contrast agent in T2 NMR imaging" *Magnetic Resonance Imaging* vol.4 (1986), 437-440.

[55] Lönnemark, et al., "Effect of superparamagnetic particles as oral contrast medium at magnetic resonance imaging - A phase I clinical study" ; Holtås, et al., "Signal alterations, artifacts and image distortion induced by a superparamagnetic contrast medium" .

[56] Blume, *Insight and Industry* , e.g. p.195-217.

[57] Ericsson, A, et al., "Proton Relaxation in a Multicompartmental System with Exchange, Simulating Human Tissue" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.26 (1985), 745-751; Jung, B., et al., "Selective Properties of Trains of Real and Complex Rf Micropulses in Slice-Selective Spin-Echo MRI" *Upsala Journal of Medical Sciences* vol.91 (1986), 37-43; Sperber, G. O., et al., "Improved Formulas for Signal Amplitudes in Repeated NMR Sequences - Applications in NMR Imaging" *Magnetic Resonance in Medicine* vol.3 (1986), 685-698; Ericsson, A., et al., "Calculation of MRI Artifacts Caused by Static-Field Disturbances" *Physics in Medicine and Biology* vol.33 (1988), 1103-1112; Sperber, G. O., et al., "NOTE - A Fast Method for T1 Fitting" *Magnetic Resonance in Medicine* vol.9 (1989), 113-117; Sperber, G. O., et al., "Fast Methods for Fitting Biexponentials Especially Applicable to MRI Multiecho Data" *Physics in Medicine and Biology* vol.35 (1990), 399-411.

[58] See also Blume's similar remark about the early disputes on MRI: Blume, *Insight and Industry* , p.223.

[59] See also my analysis of Larissa Bilaniuk's talk in Chapter 4, showing that what was visible on an MR image was defined by difference: difference between images and between parts of the same image.

[60] Joyce, "From Numbers to Pictures" .

[61] In fact one problem is that Joyce takes for granted that MRI's "final", contemporary form is one that "now produces grey scale images of the inner body" which are "[t]he representation of the data solely as an anatomical picture". Joyce's implicit understanding that MRI data is *prior to* MRI images contributes to her naturalization of the forms of MRI representations.

In my view, MRI has been used in far more different ways throughout its history, as an even superficial review of scientific publications in MRI research in the 1980s and 1990s quickly shows. Reviewing such a history of MRI practice also shows that an MRI image is not simply the representation of data, but that the relations between the visual and the quantitative are irremediably intertwined. (About MRI scans being more than digital representations, i.e. more than visualization *of* data, see Chapter 5 in this dissertation.)

However, with this I do not mean to dismiss Joyce's view that the visual character of MRI has dominated its technological development and medical use. Rather, I want to argue that no practice of MRI has been purely visual, and that quantitative practices have been pursued and played a central part throughout the history of MRI. (About the actors' perceived tensions between visual and quantitative visions of MRI, see Chapter 6 in this dissertation.)

[62] Joyce, "From Numbers to Pictures" .

INTERLUDE: SCIENCE PORN & STRIPPING THE BODY

[1] Schultz, Willibrord Weijmar, et al., "Magnetic resonance imaging of male and female genitals during coitus and female sexual arousal" *BMJ* vol.319 (1999), 1596-1600

[2] Cartwright, *Screening The Body* , p.107-142; Jülich, *Skuggor av sanning* , p-71-108, 147-178.

[3] Cartwright, *Screening The Body* , p.121.

[4] Brown, Fredric, *Martians, Go Home* (New York: Bantam Books, 1955). Jülich brings up *Superman* (1948) and a few other titles as examples of movies where X ray was used as a metaphor for (extraordinary) vision. See Jülich, *Skuggor av sanning* , 177.

[5] bstuder, *The Daily Shave #MRI Sex Machine [YouTube video]* (2006), http://www.youtube.com/watch?v=1qZLFO4NWDQ, accessed on May 21, 2007. All following references to Brian and The Daily Shave are based on that source, which hence is not referred to in additional notes.

[6] Cartwright, *Screening The Body* , 120.

[7] The following excerpt is illustrative of this defensiveness:

"Our search started in 1991 when one of us (PvA) saw a black and white slide of a midsagittal magnetic resonance image of the mouth and throat of a professional singer who was singing "aaa." He remembered Leonardo's drawing [*The Copulation*] and wondered whether it would be possible to take such an image of human coitus. We decided to try, as an ad hoc "instrument-oriented" study, despite the unscientific and other irrelevant reactions we expected and received: honi soit, qui mal y pense."

Schultz, et al., "Magnetic resonance imaging of male and female genitals during coitus and female sexual arousal" , 1597

[8] Ibid., 1599.

[9] Ibid., 1599.

[10] Ibid., 1599. These words of Schultz et al. follow their quoting of Ludwik Fleck: "In science, just as in art and in life, only what is true to culture is true to nature." (Fleck, Ludwik, *Genesis and Development of a Scientific Fact* (Chicago: University of Chicago Press, 1979 [1935]), p.35) However, the authors obviously refashioned Fleck's meanings of nature and culture in their own concluding sentence.

[11] Cohn, Simon, "Increasing Resolution, Intensifying Ambiguity: An Ethnographic Account of Seeing Life in Brain Scans" *Economy and Society* vol.33 (2004), 52-76, p.73.

CHAPTER 4: SEEING ALL OUR PATIENTS' BRAINS

1 Martensen, *The Brain Takes Shape* , p.202.

2 Ibid. See for instance the following excerpt, p.65 (italics in original): "Moreover, his [Descartes's] disciples extended the tactic to the illustrations of *De Homine/L'homme* by frequently depicting body parts as *solids* while the explanatory texts characterized their activity in terms of interactions between their pores and/or cavities and vital and animal spirits. Additionally, both *De Homine* and *L'homme* interlarded realistic illustrations of heart and brain with highly diagrammatic outline drawings of brain, nerve, and external objects. In doing so, they were trading on readers' expectations of the emerging *likeness* print culture that illustrations purporting to display the new visible inner world of natural bodies, including human, would observe post-Vesalian visual manners of representing the *real*."

3 Ibid., p.87-88; 91.

4 Ibid., p.96.

5 Ibid., p.208-209.

6 Oldendorf, *The Quest for an Image of the Brain* ; Dumit, *Picturing Personhood* ; Martensen, *The Brain Takes Shape* ; Beaulieu, *The Space Inside the Skull* .

7 On maverick scientists, cf. Adele E. Clarke's historical account of maverick scientists' contribution to the development of contraceptives: Clarke, Adele E, "Maverick Reproductive Scientists and the Production of Contraceptives, 1915-2000+" in *Bodies of Technology: Women's Involvement with Reproductive Medicine*, eds. Ann Rudinow Saetnan, et al. (Columbus, Ohio: Ohio State University Press, 2000).

8 *Vetandets värld*. P1, December 3, 1981, my translation.

9 Ibid.

10 Ibid., my translation.

11 Interview with Lennart Wetterberg, my translation.

12 Ibid.

13 Ibid.; Anonymous list of maps and technical documents: *Anskaffning av ritningar, kartor och tekniskt underlag för området kring S:t Görans sjukhus (maj 1984), för lokalisering av befintliga och ev. framtida störningskällor som avger elektromagnetiska fält och vagabonderande elström, [May 1984]*, Lennart Wetterberg private archives.

14 List of applications, FRN/FINDU: *Utlysning av medel för dyrbar vetenskaplig utrustning,* [83-10-01], Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:78, FRN; Decision list: *Åtgärdsförteckning,* 1983, Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:78, FRN; Letter from FRN to MFR: *Ansökningar avseende dyrbar utrustning våren 1984*, 84-01-31, Handlingar avseende Delegationen för finansiering av dyrbar vetenskaplig utrustning FINDU, F2F:3, FRN. Both the 1983 and 1984 applications were for 7 million SEK. The fact that this sum was defined as a complement to the donation is formulated in: Letter: *Från Bitr. Sjukhusdirektören Stockholm läns landsting Hälso- och sjukvårdsnämnden Västra förvaltningsområdet till Kansliavdelningen, Central förvaltning: Markdisposition för placering av MNR[sic]-enhet vid psykiatriska kliniken, S:t Görans sjukhus, May, 24, 1984*, Lennart Wetterberg private archives.

15 "Letter: Från Bitr. Sjukhusdirektören, May 24, 1984...". The difficult aspect of this was that the county council had a financial responsibility for health care — the *clinical use* of NMR — whereas *research* and education were the domain of the Karolinska Institute.

16 Interview with Lennart Wetterberg; Edam, Anita, "Magnetkameran avslöjar var hjärntumören sitter": *Stockholms-Tidningen, February 19, 1984*, Lennart Wetterberg private archives.

[17] "Larissa Bilaniuk's presentation of NMR imaging…"

[18] Ibid.

[19] About early radiologists' comparison strategies, see Jülich, *Skuggor av sanning* , p.255-285.

[20] "Larissa Bilaniuk's presentation of NMR imaging…"

[21] Interview with Lennart Wetterberg.

[22] Tender from Instrumentarium Corp.: *Offert till Karolinska Institutet / Sankt Görans sjukhus ang Acutscan NMR scanner för forskningsändamål, (svar till brev 1984-08-10)*, Lennart Wetterberg private archives.

[23] Interview with Lennart Wetterberg. A paper published about the installation was published in 1985 and summed up that "The equipment […] (Acutscan Model 100) is the first imager in a production series manufactured by Palomex Instrumentarium Corp., Helsinki, Finland." (Wahlund, L-O, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" *International Journal of Technology Assessment in Health Care* vol.1 (1985), 766-771, p.766).

[24] Interview with Lennart Wetterberg.

[25] Ibid.

[26] Minutes: *Protokoll fört vid Institutionsstyrelsens sammanträde vid Karolinska institutets psykiatriska institution, S:t Görans sjukhus - Installation av 1 st. ACUTSCAN (TM), ÖSV, Psykiatriska kliniken, S:t Görans sjukhus, 1984-08-23*, Lennart Wetterberg private archives.

[27] Letter: *Från Bitr. Sjukhusdirektören Stockholm läns landsting Hälso- och sjukvårdsnämnden Västra förvaltningsområdet till Teknik- och försörjningsavdelningen, VSO: MR-kamera vid S:t Görans sjukhus (4 bilagor), August 27, 1984 (received August 29, 1984)*, Lennart Wetterberg private archives, my translation.

[28] Interview with Lennart Wetterberg.

[29] "Letter: Från Bitr. Sjukhusdirektören, August 27, 1984…"

[30] Wahlund, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" , p.766-767.

[31] Interview with Lennart Wetterberg; "The images were produced within three months of the beginning of the site preparation and two weeks after the onset of the MR imager installation", Wahlund, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" , p.766-767.

[32] See also Wahlund, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" , p.771.

[33] Dyring, Eric, "Magnetkamera läkarnas senaste hjälp: Radiovåg avbildar hjärnan": *Dagens Nyheter, December 22, 1984*, Lennart Wetterberg private archives. Similarly, the MRI device was presented as "a pure research instrument" in St. Göran's Hospital's report to the County Council on the installation of the scanner. Report by Sture Sjölund and Tore Domargård: *Rapport om installation av magnetkamera (MR) vid psykiatriska kliniken, S:t Görans sjukhus, 1985-03-05*, Lennart Wetterberg private archives.

[34] Lars-Olof Wahlund, Personal communication; Wetterberg, *"De första 30 åren"* ; Interview with Ingrid Agartz.

[35] Dyring, Eric, "Magnetkamera läkarnas senaste hjälp: Radiovåg avbildar hjärnan".

[36] Agartz, I, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" *Magnetic Resonance Imaging* vol.5 (1987), 179-187.

[37] *Vetenskap om AIDS-forskning*. TV1, June 7, 1988; 20:40-21:20.

[38] Lars-Olof Wahlund, Personal communication.

[39] Interview with Lennart Wetterberg, my translation.

[40] Agartz, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" , p.180. Thus, Wetterberg's group's object of study was the brain and its diseases although the object of psychiatry had traditionally been the mind (the Merriam-Webster Online Dictionary defines psychiatry as "a branch of medicine that deals with mental, emotional, or behavioral disorders". *Merriam-Webster Online Dictionary* (2007), http://www.britannica.com, Dictionary entry: "psychiatry". Accessed on October 15, 2007.)

[41] Interview with Ingrid Agartz.

[42] Interview with Lennart Wetterberg, my translation.

[43] Ingrid Agartz explains in our interview that other psychiatry departments, such as one at Karolinska Hospital, had been using imaging technologies (CT) in their research into the shape and size of brain regions, but that this kind brain research had not been conducted at St. Göran's Hospital (see more about that research work in Chapter 5):

Dussauge: "But you had no own [CT] equipment that you could use for research for instance?

Ingrid Agartz: No. Other groups abroad had been conducting research on computed tomography. They had early CT studies at Karolinska Hospital, they looked at the size of the ventricular system. [...] But St. Göran's conducted another kind of psychiatric research."

Interview with Ingrid Agartz, my translation.

[44] Wahlund, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" , p.771.

[45] Photos: Lars-Olof Wahlund private archives, Karolinska University Hospital Huddinge.

[46] Agartz, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" .

[47] Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , p.I:8.

[48] The clinical study is summarized in two publications, Ibid., and Wahlund, L-O, et al., "MRI in psychiatry: 731 cases" *Psychiatry Research* vol.45 (1992), 139-140. The following section is based on these two publications when no other reference is mentioned.

[49] About MRI's imaging planes, see also Chapter 3.

[50] Another example was as follows: "A 64-year old man who since 1938 had repeatedly been hospitalized for a schizophrenic disorder. The psychotic periods were reported to be unusually poor in symptoms. The patient showed a marked inability to master affects. The anamneses [preliminary case histories of the patient] further revealed an overconsumption of alcohol and an 11-year exposure to trichloroethylene. The patient displayed during the current clinical examination an impairment of short- and long-term memory as well as overaggressive behavior. There were no further neurological symptoms. An MR examination showed an obstructive hydrocephalus with the localization of a high signal-intensity process between the third and fourth ventricle."

Agartz, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" , p.182-183.

[51] The clinical study is summarized in two publications, Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , and Wahlund, et al., "MRI in psychiatry: 731 cases" .

[52] Agartz, Ingrid, *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization* (Diss.; Stockholm: Karolinska Institutet, 1992), p.55.

[53] Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , p.I:8-I:9.

[54] E.g. Interview with Ingrid Agartz; Interview with Lennart Wetterberg; Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients"

Quote from Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , p.I:4-I:5.

[55] Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , p.I:12.

[56] For instance, Wahlund and his colleagues wrote retrospectively that what had been first thought of as a research tool soon turned out to be a clinical device in its own right in Ibid., p.I-4.

[57] Epstein, Steven, *Impure Science: AIDS, Activism and the Politics of Knowledge* (Berkeley, Los Angeles, London: University of California Press, 1996), p.45-48, 55; Broström, Christina, "Hivinfekterade med långsam eller ingen sjukdomsutveckling" *Perspektiv på hiv* (2000), ; Pehrson, Pehrolov, et al., "AIDS hos homosexuella män - första fallen i Sverige" *Läkartidningen* vol.80 (1983), 545-548.

[58] Moberg, Lars, et al., "Venereologisk undersökning i Stockholm: Var tredje "frisk" homosexuell man hade behandlingskrävande infektion" *Läkartidningen* vol.81 (1984), 2747-2752, my translation.

[59] "Bekräftelse från USA: AIDS-virus finns i Sverige [Meddelande]" *Läkartidningen* vol.81 (1984), 2788: "Antibodies against the virus that is considered to cause AIDS [...] have been found in the blood of Swedish homosexuals with chronic lymphatic node enlargement. Since the article on page 2747 in this issue was written, the Swedish National Bacteriological Laboratory has received a response from the USA, where a hundred blood samples had been sent for analysis. It was thereby confirmed that the AIDS virus is in Sweden. All samples from Swedish AIDS patients contained antibodies against HTLV III, the virus that presumably causes AIDS, whereas the samples of the control group were negative." My translation.

[60] See e.g. Susanne Sontag, *AIDS and its Metaphors* (1989); Paula Treichler, *How to Have Theory in an Epidemic* (1999)—who speaks of "an epidemic of signification"; Epstein, *Impure Science: AIDS, Activism and the Politics of Knowledge* .

[61] Ibid., p.47-178.

[62] Snider, WD, et al., "Neurological complication of acquired immune deficiency syndrome: analysis of 50 patients" *Annals of Neurology* vol.14 (1983), 403-18; Ho, DD, et al., "Isolation of HTLV-III from cerebrospinal fluid and neural tissues of patients with neurologic syndromes related to the acquired immunodeficiency syndrome" *New England Journal of Medicine* vol.313 (1985), 1493-1497; Shaw, George M., et al., "HTLV-III Infection in Brains of Children and Adults with AIDS Encephalopathy" *Science* vol.227 (1985), 177-182; Groopman, Jerome E., "Clinical Spectrum of HTLV-III in Humans" *Cancer Research (Suppl.)* vol.45 (1985), 4649s-4651s; Barnes, Deborah M, "AIDS-Related Brain Damage Unexplained" *Science* vol.232 (1986), 1091-1093; Beresford, Thomas P, et al., "AIDS Encephalitis Mimicking Alcohol Dementia and Depression" *Biological Psychiatry* vol.21 (1986), 394-397; Barnes, Deborah M, "Brain Damage by AIDS under Active Study" *Science* vol.235 (1987), 1574-1577. See also Epstein, *Impure Science: AIDS, Activism and the Politics of Knowledge* , p.192-193; Sönnerborg, Anders and Lennart Wetterberg, "HIV-infektion i nervsystemet - patogenes, klinik och diagnostik" *Läkartidningen* vol.85 (1988), 1053-1055.

[63] Interview with Lennart Wetterberg, my translation.

[64] Ibid. The cooperation between St. Göran's Hospital and Roslagstull Hospital is also mentioned in Sönnerborg and Wetterberg, "HIV-infektion i nervsystemet - patogenes, klinik och diagnostik" , p.1055.

[65] On Wetterberg's work with the substance called peptide T, which was considered a possible remedy for AIDS-induced dementia, see: Wetterberg, Lennart, "Ny princip prövas

vid behandling av AIDS. Peptid kan blockera cellers receptor för HIV" *Läkartidningen* vol.83 (1986), 4189-4191; *Vetenskap om AIDS-forskning*.

[66] The purpose was here again to separate the organic from the psychological/social. In 1988, Sönnerborg and Wetterberg wrote: "Depressions and other psychiatric symptoms are [...] not unusual in HIV-infected persons [...]. From the point of view of medical treatment, and especially from psychiatry's perspective, the issue is to what extent psychiatric symptoms appear as a reaction to the knowledge of having a potentially lethal infection, and how much is caused by organic lesions. It is central to sort this out to choose psychological therapy, social planning and pharmaceutical treatment." Sönnerborg and Wetterberg, "HIV-infektion i nervsystemet - patogenes, klinik och diagnostik" , p.1053; my translation.

[67] Wetterberg, "Ny princip prövas vid behandling av AIDS. Peptid kan blockera cellers receptor för HIV" . For instance, Wetterberg wrote there (my translation): "A new possibility to follow the evolution of an HIV infection in the brain and the effects of [experimental] treatment is to use a low-field magnet camera (MRI) together with a computer. The first combined unit of this kind was developed at St. Göran's Hospital [...]. Neuropathological changes in AIDS have been studied in large materials [patient groups] in the USA and shown atrophy of various brain regions [...]. We study this pathophysiological process with MRI. We examine the patients' brain on repeated occasions and judge the anatomic changes and the metabolism in different regions (see front page of this issue)."

[68] Alexius, Birgitta, et al., "Magnettomografiundersökning: Tre av fyra HIV-1-infekterade män hade subkortikala patologiska förändringar" *Läkartidningen* vol.86 (1989), 2108-2111.

[69] Ibid., p.2108. Note the implicit assumptions in the construction of knowledge of the normal brain: The control group was also composed of non-heterosexual men, showing that sexuality was inferred to be relevant for the analysis of brain anatomy (or, to put it plainly, that non-heterosexuals shared brain properties different from heterosexuals.) See Chapter 5 about how the social/cultural permeates the medical in the research design of MRI-based psychiatric research. About gender and sexuality in brain images (PET) see also Dumit, *Picturing Personhood* , p.134-138.

[70] "[Table of contents]" *Läkartidningen* vol.83 (1986), [4137].

[71] Sönnerborg and Wetterberg, "HIV-infektion i nervsystemet - patogenes, klinik och diagnostik" ; Alexius, et al., "Magnettomografiundersökning: Tre av fyra HIV-1-infekterade män hade subkortikala patologiska förändringar" ; Sönnerborg, A, et al., "Quantitative detection of brain aberrations in human immunodeficiency virus type 1-infected individuals by magnetic resonance imaging" *The Journal of Infectious Diseases* vol.162 (1990), 1245-1251. The relationship to metabolism and physiology was, if understood, at least not described in the publications examined here. The classification method used by Wetterberg's team to create color images was more general than the HIV/AIDS study and was developed partly with other goals, see Chapter 5. The computer used for image processing was developed by Context Vision, a company based in Linköping, and used in other settings for e.g. fingerprint recognition. See *Tekniskt magasin*. TV1, April 25, 1986; 18.10-18.55.

[72] The caption for the front-page picture in the table of contents was as follows ("[Table of contents]" , my translation): "Psychiatric symptoms in AIDS patients may be caused by primary HIV infection in the brain. Through repeated MRI examinations it is possible to follow the evolution of the disease. The front page shows transversal depictions of the brain in a healthy control person (left) and a patient with AIDS (right). The red and yellow areas in the brain cortex and white matter show pathological changes, inflammatory processes. The color of the cerebrospinal fluid (CSF) in the enlarged ventricles suggest that the CSF is affected in the AIDS patient. [---] The images were obtained with a low-field MRI scanner (Acutscan) and a computer for image processing (GOP-300). Image analysis and picture: M.D. Jan Sääf, St. Göran's Hospital, Stockholm."

The text supposedly explains the picture; but concretely, it rather stated explicitly the implicit cultural convention that the viewer should look for the difference between the picture considered normal and that considered pathological. What looks like an explanation of the difference ("inflammatory processes") was hypothetical (to my knowledge, the relationship between possible inflammatory processes and T1/T2 was not established).

[73] Dumit, *Picturing Personhood* , p.144.

[74] von Proschwitz, Charlotte, "BILDEN AV AIDS", *Expressen*, June 26, 1987; "Kameran som hjälper oss att se in i hjärnan" *SVAR på primärvårdsfrågor* (1986), ; "Chok", *Det Fri Aktuelt*, July 5, 1987.

[75] von Proschwitz, "BILDEN AV AIDS", my translation.

[76] A consequence of this was that people who were the bearers of non-HIV-infected brains were constructed as one category sharing a common feature, their bodily distance from HIV, under the label "normal" or "healthy"—i.e. the "normal" was constructed against HIV brains collapsed with their bearers, HIV/AIDS patients.

[77] Dumit, *Picturing Personhood* , p.147.

[78] *Vetenskap om AIDS-forskning*. My translation.

[79] *Vetenskap om AIDS-forskning*.

[80] *Vetenskap om AIDS-forskning*. My translation.

[81] Computerized methods for image processing were high-technology in the mid-1980s; and the computer system used for classification of MRI data and tissue at St. Göran's was pioneer work in itself, according to Lars-Olof Wahlund. Wahlund also precises that the same computerized methods for the handling of MRI's multi-dimensional data were used efficiently in a collaborative project about a specific category of tumors (gliomas) with neuroradiologists and neurosurgeons at Södersjukhuset Hospital. (Lars-Olof Wahlund, Personal communication.)

[82] Which means that as the categories of "normal" and "HIV brain" are constructed, the differences *within* the group are erased.

[83] *Vetenskap om AIDS-forskning*.

[84] Ibid., my translation.

[85] Ibid., my translation.

[86] Ibid., my translation.

[87] Ibid.

[88] Dumit, *Picturing Personhood* , p.143.

[89] Ibid., for instance p.148-150.

[90] Ibid., p.100-102.

[91] Foucault, *Birth of the Clinic* .

[92] Many of the early patient cases were presented in: Agartz, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" .

[93] Joyce, "Appealing Images" ; Daston and Galison, "The Image of Objectivity" . For a thorough analysis of early radiological practice and issues of objectivity, see Jülich, *Skuggor av sanning* in which Solveig Jülich discusses early radiologists' struggle to establish themselves as a profession in terms of both establishing X rays as bearers of mechanical objectivity, and themselves as bearers of a necessary art of judgment.

[94] Lars-Olof Wahlund, Personal communication.

[95] Luhrmann, TM, *Of Two Minds: An anthropologist looks at American psychiatry* (New York: Vintage Books, 2001 [2000]), p.225, emphasis added.

[96] Dumit, *Picturing Personhood* , p.166. See also p.156-169.

[97] Wahlund, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" , p.I:12 (emphasis added).

[98] For a more general discussion about the impact of mental illness as diagnosis, and about the positions culturally available to people given such diagnoses, see Luhrmann's last chapter, "Madness and Moral Responsibility". Luhrmann, *Of Two Minds* , p.266-293.

[99] For a discussion of the neurological gaze, the body and the early use of cinematography in psychiatry see Chapter 3 "An Etiology of the Neurological Gaze" in Cartwright, *Screening The Body* , p.47-80.

[100] Luhrmann, *Of Two Minds* , p.284-295.

[101] Dumit, *Picturing Personhood* , p.139-169. Quotes p.169.

[102] Cartwright, *Screening The Body* , p.169. About radiology and screenings as surveillant gaze, see Cartwright, *Screening The Body* , p.147-57 and 168-170. Cf. also p.47-80 about a surveillant neurological gaze.

INTERLUDE: REWORKING MY OWN MRI BODY

[1] From mtrcycllvr, *Home MRI of my knee [YouTube video]* (2006), http://www.youtube.com/watch?v=Ur2J1eXosNE&NR, accessed on May 21, 2007.

[2] Hacking, Ian, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (Cambridge: Cambridge University Press, 1997 [1983]). As feminist scholars and science studies scholars have argued, "nature" is invented, not discovered. Historically, radiology's logic of revelation rejoins the modern invention of nature as an object to discover through science.

[3] See Armstrong, "Bodies of Knowledge: Foucault and the Problem of Human Anatomy" ; Cartwright, *Screening The Body* .

[4] Lisa Cartwright describes how the intimate body has been subjected to radiology's surveillant gaze through the establishment of tuberculosis (TB) and mammography (breast) X-ray screenings in the twentieth century. Cartwright, *Screening The Body* , p.143-170.

[5] benchilada, *The Fuckbrain MRI [YouTube video]* (2006), http://www.youtube.com/watch?v=_zApcbvAQ4s, accessed on May 21, 2007.

[6] Dumit, *Picturing Personhood* , p.7, 162-169.

[7] See for instance: tdawgsmitz, *MRI / I had my MRI today... [YouTube video]* (2006), http://www.youtube.com/watch?v=7u4udnJ_SYk, accessed on May 21, 2007. In this video the author says: "I have seen my brain and it is a good one".

[8] mtrcycllvr, *Home MRI of my knee [YouTube video]* . Eric's video is also posted on a multitude of other Internet sites.

[9] Sawchuk, "Biotourism" , p.10.

[10] Ibid., 21. Whole quote: "Biotourism depends upon the optical capacity to see the inner recesses and contours of the body, which can be accomplished either by cutting through the epidermal layer and peering directly inside or by the use of less invasive technology. Biotourism is the fantasy that one can voyage into the interior space of the body *without* intervening in its life processes, with silent footsteps, without leaving a trace."

[11] mtrcycllvr, *Home MRI of my knee [YouTube video]* .

CHAPTER 5: QUANTIFYING NORMAL ANATOMY

[1] Interview with Ingrid Agartz, my translation.

[2] Ibid.

[3] Ibid.

[4] Agartz, *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization* , e.g. p.56-57.

[5] Beaulieu, *The Space Inside the Skull* , p.152-158.

[6] Ibid., p.132-165.

[7] Drayer, BP, "Imaging of the Aging Brain. Part 1. Normal Findings" *Radiology* vol.166 (1988), 785-796, p.785. Drayer's publication is an extensive, 1988-state-of-the-art review of the CT studies and MRI studies of the ageing brain. On Drayer's contribution to the field of neuroradiology, see the Radiological Society of North America's online biography, accessed on December 17, 2007:

RSNA, *Burton P. Drayer* http://www.rsna.org/Media/briefings/2003/Bios/drayer.cfm.

[8] Armstrong, David, "The Temporal Body" in *Companion to Medicine in the Twentieth Century,* eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000]), p.255.

[9] Drayer, "Imaging of the Aging Brain. Part 1. Normal Findings" , p.786 (emphasis added).

[10] Agartz, Ingrid, et al., "Visual Rating of Magnetic Resonance Images of Human Cerebrospinal Fluid Spaces and White Brain Matter: Relation to Sex and Age in Healthy Volunteers" *Magnetic Resonance Imaging* vol.10 (1992), 135-142 Referring, among others, to Drayer, "Imaging of the Aging Brain. Part 1. Normal Findings" ; Drayer, BP, "Imaging of the Aging Brain. Part 2. Pathologic Conditions" *Radiology* vol.166 (1988), 797-806.

[11] Agartz, et al., "Visual Rating of Magnetic Resonance Images of Human Cerebrospinal Fluid Spaces and White Brain Matter: Relation to Sex and Age in Healthy Volunteers"

[12] Ibid.

[13] Ibid., p.138.

[14] Ibid., p.135.

[15] Wahlund, L-O, et al., "The brain in healthy aged individuals: MR imaging" *Radiology* vol.174 (1990), 675-679; Lars-Olof Wahlund, Personal communication.

[16] About changing notions of subjectivity in relation to idiosyncrasies and objectivity, see Daston and Galison, "The Image of Objectivity" .

[17] Agartz, et al., "Visual Rating of Magnetic Resonance Images of Human Cerebrospinal Fluid Spaces and White Brain Matter: Relation to Sex and Age in Healthy Volunteers" , p.137.

[18] Ibid.

[19] Prasad, "Making Images/Making Bodies" . Prasad talks about about the whole body in his description of the radiological gaze as a bifocal gaze; but the same analysis can be applied to the brain considered as a whole.

[20] The Merriam-Webster Online Dictionary defines topography both as "the art or practice of graphic delineation in detail usually on maps or charts of natural and man-made features of a place or region [---]" and as "the physical or natural features of an object or entity and their structural relationships." Topography thus conflates the methods used to create a map of a landscape and the "real" features of that landscape within the map's descriptive frame. *Merriam-Webster Online Dictionary* . Accessed on July 27, 2007.

[21] Agartz, I, et al., "Quantitative Estimations of Cerebrospinal Fluid Spaces and Brain Regions in Healthy Controls Using Computer-Assisted Tissue Classification of Magnetic Resonance Images: Relation to Age and Sex" *Magnetic Resonance Imaging* vol.10 (1992), 217-226.

[22] Dumit, *Picturing Personhood* , p.59.

[23] Agartz, *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization* , p.III-6.

[24] Agartz, et al., "Visual Rating of Magnetic Resonance Images of Human Cerebrospinal Fluid Spaces and White Brain Matter: Relation to Sex and Age in Healthy Volunteers" , p.136, emphasis added.

[25] After translation of the individuals' brain into the topographic grid of the items and scores, none of these factors were found significantly relevant to the quantitative topography of the brain in that study.

[26] Agartz, *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization* , p.III-7.

[27] Wahlund, et al., "The brain in healthy aged individuals: MR imaging" , p.676

[28] This method, and its validation and consequences were described in: Agartz, et al., "Quantitative Estimations of Cerebrospinal Fluid Spaces and Brain Regions in Healthy Controls Using Computer-Assisted Tissue Classification of Magnetic Resonance Images: Relation to Age and Sex" . See also Wahlund, et al., "The brain in healthy aged individuals: MR imaging" .

[29] Although this didn't show on the classified scans, the charting of each subject's brain was *statistical*. For each brain scan, a few pixels characteristic of brain and CSF, respectively, were manually chosen by one of the researchers. An algorithm was then performed by the computer on each pixel of the whole brain, comparing the pixel under processing to the reference pixels, and determining the probability of just this pixel belonging to either brain matter or CSF. The class found most probable, brain matter or CSF, was then attributed to the pixel. But what was invisible on the visual chart obtained this way, pixel after pixel, was the probabilistic character of this classification: each brain pixel was attributed not only a "class" label, but also a "likelihood" label. By filtering the whole map for the pixels with too low a likelihood, i.e. too little certainty about the specific pixel's classification, maps could be obtained which displayed only the "certain enough"-areas. Finally, the now classified brain-part and CSF-part of specific brain areas could be pixel-counted; metaphorically speaking, the CSF and brain areas were automatically measured from the "map". Cf. Agartz, et al., "Quantitative Estimations of Cerebrospinal Fluid Spaces and Brain Regions in Healthy Controls Using Computer-Assisted Tissue Classification of Magnetic Resonance Images: Relation to Age and Sex" .

[30] Ibid.p.226.

[31] Ibid.

[32] Ibid.

[33] van Dijck, *The Transparent Body* , p.3-4.

[34] Wahlund, et al., "The brain in healthy aged individuals: MR imaging" , p.676.

[35] Jülich, *Skuggor av sanning* , p.284 (my translation).

[36] Daston and Galison, "The Image of Objectivity" , p.123.

[37] Jülich and Pasveer make a similar point when they argue that X-rays had to be established as objective if other medical disciplines were to adopt them as a diagnostic tool. (Jülich, *Skuggor av sanning* ; Pasveer, "Knowledge of Shadows")

[38] Agartz, I, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" *Radiology* vol.181 (1991), 537-543.

[39] Interview with Ingrid Agartz, my translation.

[40] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain"

[41] Ibid., p.537. On the same theme (hopes of quantitative MRI as a way to create contrast stronger than existing visual methods), see the first empirical section of Chapter 3 in this dissertation.

[42] Lars-Olof Wahlund, Personal communication, my translation.

[43] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" , p.537: "To study disease groups, extensive series of healthy subjects are necessary, since relaxation in MR imaging depends on the nuclear MR frequency used. Other factors, including the age of the person undergoing examination, also influence relaxation values. In the present study, [...] [t]he goal was to estimate the T1 and T2 values in healthy subjects and to investigate the relation to age, sex, and laterality."

[44] The T1/T2-topography was not based on the same items/regions as in the topography described in the previous section of this chapter, but it was still based on traditional brain anatomy.

[45] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" , p.538.

[46] The six images were taken at the same level in the brain, but with different pulse sequences (measurement methods), producing intensities on each point of the image that were differently influenced by T1 and T2 in different scans. The difficulty which made algorithms necessary was that pictures of the same person were not as such geometrically compatible, and Agartz and her colleagues needed to identify the same pixels on the different scans.

[47] Beaulieu, *The Space Inside the Skull* , p.128.

[48] Ibid.p.128-129.

[49] Note that in their earlier work in exploring NMR, Agartz and others had also used pure image post-processing techniques (such as noise reduction, line and edge enhancement) to improve the "image quality". These methods had no relation to the methods discussed here. (Agartz, I, et al., "High Accuracy and Contrast Resolution in Ultra Low Field (0.02 Tesla) Magnetic Resonance Imaging" *Academic Radiology* (1986), 472-474)

[50] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" .

[51] In one study (Ibid.), age was found to correlate with the main value of T1, and in another study (Wahlund, et al., "The brain in healthy aged individuals: MR imaging"), age was found to correlate only with T1 values of frontal white matter.

[52] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" .

[53] Armstrong, "The Temporal Body" .

[54] Agartz, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" .

[55] Wahlund, et al., "The brain in healthy aged individuals: MR imaging" . The selection of "successfully aged" subjects amongst healthy volunteers was strict—only 24 out of 100 persons were accepted as research subjects. The others had been excluded on the basis of family history of dementia or psychiatric disease, history or signs of arteriosclerosis, and clinical examination.

[56] Armstrong, "The Temporal Body" , p.58.

[57] Beaulieu, *The Space Inside the Skull* .

[58] Daston and Galison, "The Image of Objectivity" .

[59] Cf. e.g. Luhrmann, *Of Two Minds* .

[60] Prasad, "Making Images/Making Bodies" .

INTERLUDE: SEEING BEYOND MATERIALITY?

[1] Purcell, Edward M., *Research in Nuclear Magnetism: Nobel Lecture, December 11, 1952* (1952), http://nobelprize.org.

[2] Hacking, *Representing and intervening* , p.39-141. The three excerpts used here are not contiguous in Hacking's text. In my assemblage of quotations I have separated them with [---].

[3] Interview with Bertil Persson, my translation.

CHAPTER 6: CELLS, FLOWS, AND RELAXATION TIMES

[1] Ibid., my translation.

[2] For more about Persson's early interest in MRI, cf. Chapter 2.

[3] Interview with Bertil Persson, my translation.

[4] Ibid., my translation.

[5] Joyce, "From Numbers to Pictures" .

[6] Freddy Ståhlberg, Personal communication, in which Ståhlberg writes (my translation): "During the 20 years of my work as MRI researcher I have experienced that radiology researchers have a broad perspective on the use of MRI technology. The publication history of my own research group over the years is an example of this: within flow-, perfusion-, and diffusion MRI research, we would never have been half as successful without a fruitful cooperation with both neuroradiologists with interest for functional [imaging with] MRI and radiologists with other specializations."

[7] Blume, *Insight and Industry* ; Holtzmann Kevles, *Naked to the Bone* ; Joyce, "From Numbers to Pictures" .

[8] In order to be able to follow Lund's work between the quantitative and the visual, I will often use the terms "NMR representations" and NMR/MRI to refer as a whole to both quantitative NMR measures and NMR images. Otherwise I use NMR to refer to quantitative measurements on samples, and MRI to refer to NMR imaging. My intention is that this will avoid naturalizing *a priori* differences between quantitative NMR measurements and NMR imaging or beteween the quantitative and the visual.

[9] In the team were Magnus Bolmsjö, a researcher in electronics working at the Radiation Physics Department, and later on Lars Malmgren, who was a technician and could work on the images. A collaborator was also Herman Helgesson, who had been working on a fusion energy project in UK, and was a recognised expert in constructing magnets adapted to the desired magnetic fields. Interview with Bertil Persson; Bertil Persson, Personal communication; Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen.

[10] Persson, Bertil, *Medicinska tillämpningar av kärnspinnresonans - NMR* (Lund: Studentlitteratur, 1982).

[11] Maybe symptomatically, Erik Boijsen, the chief clinical physician of the department of diagnostic radiology, although invited, did not attend the workshop. Representatives from MRI manufacturers had also been contacted; the workshops' speakers were Persson, the Ph.D student Freddy Ståhlberg and electronics researcher Bolmsjö from the physics department, whose contributions dealt with basic physical and technical principles of NMR and NMR imaging devices. Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen; Invitation: *Inbjudan till workshop om medicinska tillämpningar av NMR. 19-20 nov 1982, Landstingets kursgård i Hörby (Skåne),* Freddy Ståhlberg private archives / Department of Medical Radiation Physics, Lund University Hospital.

[12] Freddy Ståhlberg's notes: *from Workshop on medical applications of NMR, 19-20 Nov 1982 in Hörby,* Freddy Ståhlberg private archives / Department of Medical Radiation Physics, Lund University Hospital.

[13] Bertil Persson, Personal communication; Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen.

[14] Booklet: *NMR-workshop II på institutionen för radiofysik, Lund, 6/6-8/6 - 1983,* Freddy Ståhlberg private archives / Department of Medical Radiation Physics, Lund University Hospital

[15] Persson, B, et al., "Design and application of a proton NMR imaging system based on a window frame type of magnet" in *Progress in Nuclear Medicine, vol.8: Magnetic Resonance in Medicine and Biology,* eds. MA Hopf and FW Smith (Basel: Karger, 1984)

[16] Bertil Persson, Personal communication.

[17] According to Persson today, their prototype was "another type of MR", it was an open machine, built on new principles—among others, magnetic fields that were spatially limited to the examination platform. Extended to a full-scale, full-body version, it would mean that the patient would not need be placed within a tube, and could be examined freely, permitting, for example, surgical interventions under MRI control. Such open devices were developed commercially in Finland and USA in the mid-1990s. Interview with Bertil Persson; Bertil Persson, Personal communication.

[18] About Freddy Ståhlberg: Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen; Bertil Persson's CV.

[19] Interview with Bertil Persson, my translation. The definition of histopathology used here comes from *Merriam-Webster Online Dictionary* , accessed on December 18, 2007.

[20] As I have explained in more detail in Chapters 1 and 3, T1 and T2 were quantitative time values which reflected protons' interaction with their molecular environment. They were called "relaxation times", and concretely they characterized the time it took protons to lose energy through interactions with neighboring molecules (a process of loss called relaxation) after being excited with radiofrequency waves sent by the NMR/MRI device.

[21] Persson, *Medicinska tillämpningar av kärnspinnresonans - NMR* , p.79, my translation.

[22] An example of such argumentation is the following excerpt from a publication by the the Lund MRI group: "Knowledge of the ranges of T1 and T2 values in normal and diseased tissue at a certain magnetic field strength is a prerequisite for choosing the optimal puls [sic] sequence, repetition time and delay time in MR imaging [ref]." (Larsson, E-M, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 231-234, p.233).

Similarly illustrated by statements such as: "In vitro [quantitative] determinations of proton magnetic resonance (MR) relaxation times are useful as a basis for choosing the pulse repetition time and delay time required for optimum contrast and sensitivity in magnetic resonance imaging" (Györffy-Wagner, Z, et al., "Proton Magnetic Resonance Relaxation Times T1 and T2 Related to Postmortem Interval. An Investigation of Porcine Brain Tissue" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 115-118, p.115); "These in vitro differences regarding relaxation times in various types of tumours of the central nervous system, dependent on various types of tissue alterations, should be of interest for the interpretation of in vivo images" (Englund, E, et al., "Tumours of the Central Nervous System - Proton MR Relaxation T1 and T2 and Histopathologic Correlates" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 653-659, p.653); "To visualize [...] [white matter infarctions] on magnetic resonance imaging (MRI), knowledge of MR relaxation times associated with this histopathology is important."

(Englund, E, et al., "Correlations Between Histopathologic White Matter Changes and Proton MR Relaxation Times in Dementia" *Alzheimer´s Disease and Associated Disorders (ADAD-IJ)* vol.1 (1987), 156-170).

A *pulse sequence* was a programmed chain of command for two aspects of an experiment or examination: first, it determined the excitation of protons with NMR (sending radiofrequency waves with a given repetition time). Second, it commanded the process of measuring back the NMR signals provoked in the body, for example by defining a given acquisition time (how long the NMR device would be "listening" to the body's NMR signals). Pulse sequences commanded the profile and timing of magnetic gradients, radiofrequency waves, etc., and therefore determined how physical entities like T1 and T2 influenced the recorded NMR signal from the body. As a result, a pulse sequence was usually good at providing one kind of information: either T1 or T2; and in specific value ranges (e.g. for measurements of longer T2's, another pulse sequence would have to be used than for measuring short T2's).

[23] Cartwright, *Screening The Body* , p.81-106. Quote p.90. The notion of "cleaning up" of images is discussed by Amman, Klaus and Karen Knorr Cetina, "The Fixation of (Visual) Evidence" in *Representation in Scientific Practice,* eds. Michael Lynch and Steve Woolgar (Cambridge: MIT Press, 1990).

[24] Györffy-Wagner, et al., "Proton Magnetic Resonance Relaxation Times T1 and T2 Related to Postmortem Interval" , p.115, emphasis added.

[25] Ibid.; Larsson, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" .

[26] Györffy-Wagner, et al., "Proton Magnetic Resonance Relaxation Times T1 and T2 Related to Postmortem Interval" , p.115-116.

[27] Larsson, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" , p.233.

[28] Ibid. p.233-234. See also Györffy-Wagner, et al., "Proton Magnetic Resonance Relaxation Times T1 and T2 Related to Postmortem Interval" .

[29] See e.g. Larsson, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" ; Englund, E, et al., "Relaxation Times in Relation to Grade of Malignancy and Tissue Necrosis in Astrocytic Gliomas" *Magnetic Resonance Imaging* vol.4 (1986), 425-429.

[30] Larsson, *MRI of the Cervical and Thoracic Spine and the Spinal Cord* , p.6.

[31] Ibid., p.6.

[32] Waldby, "The Visible Human Project" , p.29. Cf. also Åhrén Snickare, *Döden, kroppen och moderniteten* , 98.

[33] In the broader landscape of MRI research, this characterization of different diseases also encompassed the other pathologies such as infarctions or bleedings, although the early research in Lund was focused on tumors.

[34] See e.g. following quote: "Possible regional variation of T1 and T2 within the brain becomes important in the evaluation of discrete pathologic changes, *especially when there is no distortion of the normal anatomy*." Larsson, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" , p.231. Cf. also Chapter 3 in this dissertation.

[35] This study is documented in detail in the following two publications, on which I have based my analysis: Englund, et al., "Tumours of the Central Nervous System..." ; Englund, et al., "Relaxation Times in Relation to Grade of Malignancy..." .

[36] An example of such transformation is given in the following excerpt from a research publication: "Before MR measurements, small pieces from each sample were taken for

determination of water content, using the wet-to-dry matter method. [---] After the [MR] measurements, each sample was fixed in formalin and paraffin-embedded in its entirety. They were sectioned at 5 µm, stained with hematoxylin and eosin and van Gieson and then studied histologically with regard to type of tissue and homogeneity of each tumour sample." Englund, et al., "Tumours of the Central Nervous System..." , p.653-654.

[37] Histopathology means "a branch of pathology concerned with the tissue changes characteristic of disease" (*Merriam-Webster Online Dictionary* , February 19, 2008).

[38] Here is an example of categorization and characterization: "For all tumour groups the admixture of other tissue components (blood, fibrohyaline scarring, normal white or grey matter) was evaluated in each sample. For the astrocytomas each sample was ranked according to degree of malignancy (grades I-II, II-III and III-IV) [...]. The proportion of necrosis was estimated in both the astrocytomas and the metastases [...]. The meningiomas were divided in two groups: one with a small and the other with a considerable component of fibrosis [...]." Englund, et al., "Tumours of the Central Nervous System..." , p.654.

[39] Ibid.

[40] Ibid., p.657.

[41] Englund, et al., "Relaxation Times in Relation to Grade of Malignancy..." .

[42] Ibid. Quote p.425.

[43] Englund, et al., "Tumours of the Central Nervous System..."

[44] Englund, et al., "Relaxation Times in Relation to Grade of Malignancy..." .

[45] That this relation "seemed" to exist at first glance on the graphs was not enough; statistical analysis was performed to confirm or falsify the apparent relations between NMR characteristics and histopathological features.

[46] Prasad, "Making Images/Making Bodies" .

[47] Anthropologist Joe Dumit makes a similar point about the production of PET scans, in which different experimental procedures for different PET labs make different groups' results (PET scans and their interpretation) hardly comparable with each other, which reveals the fundamental instability of what is represented with PET (Dumit, *Picturing Personhood* , e.g. p.55-57, 92-95.)

[48] Efforts to characterize tumors with MR values were not very successful. See e.g. Andersson, T, et al., "Effect of Interferon on T1 Relaxation Times of Liver Metastases from Endocrine Gastrointestinal Tumours" *Acta Radiologica* vol.29 (1988), 21-25: "So far, quantification of relaxation rates have not been very useful for tumour characterization (8, 12, 13, 31) and few positive reports have been published (23, 27)." (p.21)

[49] Englund, et al., "Tumours of the Central Nervous System..." , p.658.

[50] Cf.: "Based upon results from in vitro studies, it has been advocated that MRI should be able to discriminate between normal and malignant tissues [...], as well as between tumours of different growth rate [...]. These proposals, however, have not been accepted by others, who have found great overlap between the MR parameters of benign and malignant tissue [...]." Nyman, R., et al., "An attempt to characterize malignant lymphoma in spleen, liver and lymph node with magnetic resonance imaging" *Acta Radiologica* vol.28 (1987), 527-533, p.527.

[51] Prasad, "Making Images/Making Bodies" , p.304.

[52] Cartwright, *Screening The Body* , p.87-88.

[53] Ibid., p.83.

[54] Englund, et al., "Correlations Between Histopathologic White Matter Changes and Proton MR Relaxation Times in Dementia" .

[55] Persson, *Medicinska tillämpningar av kärnspinnresonans - NMR* , p.105, my translation.

[56] The history of the development of MRI visualization of flows appears as that of what Rebecka McSwain has called a "forward salient". McSwain proposes that we consider how actors sometimes reconceptualize crucial problems in sociotechnical work ("reverse salients" in classical literature on large technical systems) into a new central feature of a technology. A "forward salient," i.e. a new direction of sociotechnical development, emerges as the result of this reconceptualization. McSwain, Rebecka, "The Social Reconstruction of a Reverse Salient in Electrical Guitar Technology: Noise, the Solid Body and Jimi Hendrix" in *Music and Technology in the Twentieth Century,* ed. Hans-Joachim Braun (Baltimore: John Hopkins University Press, 2002).

[57] Cartwright, *Screening The Body* , p.90.

[58] Battocletti, Joseph H, et al., "The NMR Blood Flowmeter - Theory and History" *Medical Physics* vol.8 (1981), 435-443; Persson, *Medicinska tillämpningar av kärnspinnresonans - NMR* , p.103-105.

[59] Constantinesco et al. refer to Mansfield's early description of the problems caused by flow—and his favorite solution, shorter examination times with his own technique, echo-planar imaging (EPI). (Constantinesco, A, et al., "Spatial or Flow Velocity Phase Encoding Gradients in NMR Imaging" *Magnetic Resonance Imaging* vol.2 (1984), 335-340): Mansfield, P. Critical evaluation of NMR imaging techniques. *Proceedings of the Int. Symp. on Nucl. Mug. Res. Im. Winston-Salem*: 81-88; 1981; Ordidge, R.J.; Mansfield, P.; Doyle, M.; Coupland, R. Real time moving images by NMR. *Proceedings of the Int. Symp. on Nucl. Mag. Res. Im. Winston-Salem*: 89-92; 1981.

[60] Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen. Examples of the early publications showing that the imaging of flow was envisaged as possible: Crooks, L., et al., "Tomography of hydrogen with nuclear magnetic resonance" *Radiology* vol.136 (1980), 701; Crooks, L.E., et al., "Visualization of cerebral and vascular abnormalities by NMR imaging: The effects of imaging parameters on contrast" *Radiology* vol.144 (1982), 843.

According to The MR Physics Research Group, *MR Physics - Progress report 2004* (2004), http://www.jubileum.lu.se/MR_physics/printable.pdf (accessed on June 9, 2005), the two following examples are probably the first publications reporting NMR-imaging methods specifically for flow imaging: Moran, Paul R, "A flow velocity zeugmatographic interlace for NMR imaging in humans" *Magnetic Resonance Imaging* vol.1 (1982), 197-203; Singer, JR and LE Crooks, "Nuclear Magnetic Resonance Blood Flow Measurements in the Human Brain" *Science* vol.221 (1983), 654-656. In contrast, radiologist Charles B Higgins mentions the following article as marking the introduction of velocity mapping: Underwood SR, Firmin DN, Klipstein RH, Rees RSO, Longmore DB. Magnetic resonance velocity mapping: clinical applications of a new technique. *Br Heart J* 1987;57:404-412 (cited in Higgins, CB and H Sakuma, "Heart Disease: Functional evaluation with MR imaging" *Radiology* vol.199 (1996), 307-315).

[61] Burt, C Tyler, "NMR Measurements and Flow" *Journal of Nuclear Medicine* vol.23 (1982), 1044-1045, p.1044.

[62] Ibid.p.1044: "Though nuclear magnetic resonance (NMR) has been a tool of the chemist and physicist for some time, its entry into the medical scene has been prompted largely by proton NMR imaging (NMRI) and to a lesser extent by metabolic imaging. [---] However, flow measurements by NMR have been discussed for some time. [---] Interestingly though, flow measurements in the mode most commonly discussed in the past have not made the penetration into common medical practice in the same sense that NMRI methods have."

[63] Ibid.p.1044.

[64] Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen, my translation.

[65] Freddy Ståhlberg, L Herrnsdorf and Bertil Persson (1983) *NMR-flow measurements I: A method of measuring fluid flows using a NMR-analyzer (manuscript),* quoted in Bertil Persson's CV; Ståhlberg, F, *MR Flow Imaging: A survey of methods for flow imaging using NMR technique*, LUNFD6/ (NFRA-3053) / (1-29) / (1984); LUMEDW/ (MERI-3053) / (1-29) / (1984), 1984; Ståhlberg, F and B Persson, *Flödesmätningar på dialysatorer med scintillationskamera- och NMR (kärnspinnresonans)-teknik*, LUNFD6/ (NFRA-3046) / (1-30) / (1984); LUMEDW/ (MERI-3046) / (1-30) / (1984), 1984.

[66] Ståhlberg, *MR Flow Imaging: A survey of methods for flow imaging using NMR technique*, , p.12.

[67] Ståhlberg's early work may be traced in the following reports: Ståhlberg, Freddy and Lars Herrnsdorf, "En metod för flödesmätningar med hjälp av NMR-teknik [Poster]" in *Läkaresällskapets Riksstämma 30 nov-2 dec 1983: Program och sammanfattningar (Svenska läkaresällskapets handlingar 92 (1983):8)*, 1983); Ståhlberg and Persson, *Flödesmätningar på dialysatorer med scintillationskamera- och NMR (kärnspinnresonans)-teknik*, ; Ståhlberg, F, et al., *Flow measurements on the Lund 0.3 T FONAR unit - Preliminary results and future aspects*, LUNFD6/(NFRA-3075)/(1-13)/(1986); LUMEDW/(MERI-3075)/(1-13)/(1986), 1986.

[68] Interview with Bo Nordell. Nordell's dissertation (Karolinska Institute) was published in 1983, with the title "Production of photoneutron beams and radionuclides by photonuclear reactions using a 50 MeV racetrack microtron".

[69] Letter from Anders Hemmingsson to MFR: *Concerning Nordell, Greitz and Ståhlberg's application, 1984*, Anders Hemmingsson private archives / Department of diagnostic radiology, Uppsala University Hospital.

[70] The MR Physics Research Group, *MR Physics - Progress report 2004* .

[71] Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen, my translation.

[72] The MR Physics Research Group, *MR Physics - Progress report 2004* .

[73] Ståhlberg, F, *NMR Flow Imaging: A Study of Flow Perpendicular to the Imaging Plane Using 0.08 - 1.5 T NMR Imaging Units* (Diss.; Lund: Lund, 1987). However, another branch of studies developed internationally. Work on amplifying the decrease in signal intensity where there was flow in the blood vessels enabled the development of MR angiography: the imaging of vessels with MRI. The blood was made to disappear from MR representations, leaving a clean image of vessels as dark voids with clear contours (see e.g. The MR Physics Research Group, *MR Physics - Progress report 2004* .) In other words, the MRI methods which emphasized the temporal information of signals created physiological bodies, whereas those which used the spatial effects of flow produced—again—anatomical bodies.

[74] Bergstrand, G, et al., "Cardiac Gated MR Imaging of Cerebrospinal Fluid Flow" *Journal of Computer Assisted Tomography* vol.9 (1985), 1003. See also Bergstrand, G, et al., "Cerebrospinal fluid flow studied with gated magnetic resonance imaging during the various parts of the cardiac cycle" *Acta Radiologica. Supplementum* vol.369 (1986), 490-491.

[75] Ståhlberg, F, et al., "Determination of flow velocities from magnetic resonance multiple spin-echo images. A phantom study" *Acta Radiologica* vol.28 (1987), 643-648.

[76] Henriksen, O, et al., "In vivo evaluation of femoral blood flow measured with magnetic resonance" *Acta Radiologica* vol.30 (1989), 153-157.

[77] Ståhlberg, F, et al., "A method for MR quantification of flow velocities in blood and CSF using interleaved gradient-echo pulse sequences" *Magnetic Resonance Imaging* vol.7 (1989), 655-667. Examples of the SFG's further use and developments of these methods in CSF studies can be found the following publications: Thomsen, Carsten, et al., "Fourier Analysis of Cerebrospinal Fluid Flow velocities: MR Imaging Study" *Radiology* vol.177 (1990), 659-665; Greitz, D, et al., "Pulsatile Brain Movement and Associated Hydrodynamics Studied by

Magnetic Resonance Phase Imaging. The Monro-Kellie Doctrine Revisited" *Neuroradiology* vol.34 (1992), 370-380.

[78] See e.g. Bergstrand, et al., "Cerebrospinal fluid flow studied with gated magnetic resonance imaging during the various parts of the cardiac cycle" ; Ståhlberg, et al., "Determination of flow velocities from magnetic resonance multiple spin-echo images. A phantom study"

[79] Nordell, B, et al., "A rotating phantom for the study of flow effects in MR imaging" *Magnetic Resonance Imaging* vol.6 (1988), 695-705.

[80] Ibid.

[81] Thomsen, et al., "Fourier Analysis of Cerebrospinal Fluid Flow velocities" .

[82] Ibid.

[83] See Cartwright, *Screening The Body* about cinematographic techniques and nineteenth century/early twentieth century physiology.

[84] Ibid., p.86.

[85] Ibid., p.86.

[86] Fox Keller, Evelyn, "Models of and Models for: Theory and Practice in Contemporary Biology" *Philosophy of Science* vol.67 (2000), S72-S86. Fox Keller's further point is that "models for" should therefore not be criticized as theories or assertions of what things are (which philosophers attending the issue of models had tended to do). Soraya de Charadevian's *Models* attempts a similar move by displacing the traditional—philosophical—focus from theoretical models, models *of*, towards the effects and practice of material models, thus considering them primarily as models *for* doing rather than expressions of theory. de Chadarevian, Soraya and Nick Hopwood (eds.), *Models: The Third Dimension of Science* (Stanford, CA: Stanford University Press, 2004).

[87] About these three themes, see also, respectively: Cartwright, *Screening The Body* ; Dumit, *Picturing Personhood* ; Prasad, "Making Images/Making Bodies" .

[88] About the almost-agency of objects and technological apparatus, see Cartwright, *Screening The Body*, p.85-90.

CHAPTER 7: A KALEIDOSCOPE OF GAZES

[1] Bolter, Jay David and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, MA: The MIT Press, 2000 [1999])

[2] Ibid., p.19.

[3] Ibid., p.15. See also their concluding words p.270-271.

references

UNPUBLISHED SOURCES

archives

Medicinska forskningsrådet, MFR

A1A:24	Rådets protokoll
B3B:6,7	Projektkataloger [Årsredogörelser]
E1:394,395,398	Diarieförd allmän korrespondens
F1:784,992,1136	Ansökningshandlingar

Forskningsrådsnämnden, FRN

A1:2	Sammanträdesprotokoll
F2F:2,3,15,78	Handlingar avseende Delegationen för finansiering av dyrbar utrustning FINDU

Statens ljud- och bildarkiv, SLBA

Vetandets värld. P1, December 3, 1981
Sjukhusmagneten. TV2, October 10, 1984; 21.00-21.35
Hälsomaskinen. TV2, October 15, 1984; 20.00-20.35
Tekniskt magasin. TV1, April 25, 1986; 18.10-18.55
Vetenskap om AIDS-forskning. TV1, June 7, 1988; 20:40-21:20

private archives

Anders Hemmingsson / Department of Diagnostic Radiology, Uppsala University Hospital,
Bo Nordell / MR-center, Karolinska Hospital, Stockholm,
Bertil Persson,
Freddy Ståhlberg / Department of Medical Radiation Physics, Lund University Hospital,
Lars-Olof Wahlund / Karolinska University Hospital Huddinge,
Lennart Wetterberg.

internet

The MR Physics Research Group, *MR Physics - Progress report 2004* (2004), http://www.jubileum.lu.se/MR_physics/printable.pdf, Accessed on June 9, 2005

Author unknown, *Homer Simpson Brain* http://www.simpsonstrivia.com.ar/wallpapers/homer-simpson-wallpaper-brain.htm, May 19, 2007

benchilada, *The Fuckbrain MRI [YouTube video]* (2006), http://www.youtube.com/watch?v=_zApcbvAQ4s, May 21, 2007

Bloch, Felix, *The Principle of Nuclear Induction: Nobel Lecture, December 11, 1952*, http://nobelprize.org, August 10, 2006

bstuder, *The Daily Shave #MRI Sex Machine [YouTube video]* (2006), http://www.youtube.com/watch?v=1qZLFO4NWDQ, May 21, 2007

Encyclopædia Britannica Online, www.britannica.com

www.google.se, November 6, 2007.

Hornak, Joseph P, *The Basics of MRI* http://www.cis.rit.edu/htbooks/mri/, March 1, 2004

Lauterbur, Paul, *All Science is Interdisciplinary - From Magnetic Moments to Molecules to Men. Nobel Lecture, December 8, 2003* (2003), http://nobelprize.org, August 10, 2006

Mansfield, Peter, *Snapshot MRI: Nobel lecture, December 8, 2003* (2003), http://nobelprize.org, July 29, 2006

Merriam-Webster Online Dictionary (2007), http://www.britannica.com

mtrcycllvr, *Home MRI of my knee [YouTube video]* (2006), http://www.youtube.com/watch?v=Ur2J1eXosNE&NR, 21 May 2007

Nobel Prize in Physiology or Medicine 2003, Press Release (2003), http://nobelprize.org, July 29, 2006

Purcell, Edward M., *Research in Nuclear Magnetism: Nobel Lecture, December 11, 1952* (1952), http://nobelprize.org, August 10, 2006

Ringertz, Hans, *Presentation Speech for the Nobel Prize in Physiology or Medicine 2003* (2003), http://nobelprize.org, July 29, 2006

RSNA, *Burton P. Drayer* http://www.rsna.org/Media/briefings/2003/Bios/drayer.cfm, December 17, 2007

tdawgsmitz, *MRI / I had my MRI today... [YouTube video]* (2006), http://www.youtube.com/watch?v=7u4udnJ_SYk, 21 May 2007

oral sources

Interview with Ingrid Agartz, Oslo, April 20, 2005
Interview with Anders Ericsson, Uppsala, February 12, 2003
Interview with Håkan Eriksson, Stockholm, February 23, 2004
Interviews with Anders Hemmingsson, Uppsala, September 9, 2002; November 5, 2002; January 22, 2003.
Interview with Bo Nordell, Stockholm, February 20, 2004
Interview with Bertil Persson, Stockholm, November 26, 2003
Bertil Persson, Personal communication, March 25, 2004
Interview with Tore Scherstén, Stockholm, March 27, 2004
Interview with Freddy Ståhlberg, Holger Pettersson, Erik Boijsen, Lund, October 13, 2003
Freddy Ståhlberg, Personal communication, January 10, 2008
Lars-Olof Wahlund, Personal communication, February 18, 2008
Interview with Lennart Wetterberg, Stockholm, November 2, 2005

PUBLISHED SOURCES & LITERATURE

A

Agartz, I, et al., "High Accuracy and Contrast Resolution in Ultra Low Field (0.02 Tesla) Magnetic Resonance Imaging" *Academic Radiology* (1986), 472-474

Agartz, I, et al., "T1 and T2 Relaxation Time Estimates in the Normal Human Brain" *Radiology* vol.181 (1991), 537-543

Agartz, I, et al., "Quantitative Estimations of Cerebrospinal Fluid Spaces and Brain Regions in Healthy Controls Using Computer-Assisted Tissue Classification of Magnetic Resonance Images: Relation to Age and Sex" *Magnetic Resonance Imaging* vol.10 (1992), 217-226

Agartz, I, et al., "Magnetic Resonance Imaging at 0.02 Tesla in Clinical Practice and Research" *Magnetic Resonance Imaging* vol.5 (1987), 179-187

Agartz, Ingrid, *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization* (Diss.; Stockholm: Karolinska Institutet, 1992)

Agartz, Ingrid, et al., "Visual Rating of Magnetic Resonance Images of Human Cerebrospinal Fluid Spaces and White Brain Matter: Relation to Sex and Age in Healthy Volunteers" *Magnetic Resonance Imaging* vol.10 (1992), 135-142

Agartz, Ingrid, et al., "Goda erfarenheter av nyinstallerad lågfältsmagnetkamera" *Läkartidningen* vol.82 (1985), 4116-4121

Alač, Morana, "Negotiating Pictures of Numbers" *Social Epistemology* vol.18 (2004), 199-214

Alač, Morana and Edwin Hutchins, "I See What You Are Saying: Action as Cognition in fMRI Brain Mapping Practice" *Journal of Cognition and Culture* vol.4 (2004), 629-661

Alexius, Birgitta, et al., "Magnettomografiundersökning: Tre av fyra HIV-1-infekterade män hade subkortikala patologiska förändringar" *Läkartidningen* vol.86 (1989), 2108-2111

Amman, Klaus and Karen Knorr Cetina, "The Fixation of (Visual) Evidence" in *Representation in Scientific Practice*, eds. Michael Lynch and Steve Woolgar (Cambridge: MIT Press, 1990)

Amsterdamska, Olga and Anja Hiddinga, "The Analyzed Body" in *Companion to Medicine in the Twentieth Century*, eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000])

Andersson, T, et al., "Effect of Interferon on T1 Relaxation Times of Liver Metastases from Endocrine Gastrointestinal Tumours" *Acta Radiologica* vol.29 (1988), 21-25

"Angiografi med MRT blir smärtfri" *Läkartidningen* vol.84 (1987), 1871

Armstrong, David, "The Temporal Body" in *Companion to Medicine in the Twentieth Century*, eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000])

Armstrong, David, "Bodies of Knowledge: Foucault and the Problem of Human Anatomy" in *The Body: Critical Concepts in Sociology*, eds. Andrew Blaikie, et al. (London: Routledge, 2004)

"Avancerad scanner ger oss ny kunskap om flickoffer" *Illustrerad Vetenskap* (1997), 24

B

Barnes, Deborah M, "AIDS-Related Brain Damage Unexplained" *Science* vol.232 (1986), 1091-1093

Barnes, Deborah M, "Brain Damage by AIDS under Active Study" *Science* vol.235 (1987), 1574-1577

Battocletti, Joseph H, et al., "The NMR Blood Flowmeter - Theory and History" *Medical Physics* vol.8 (1981), 435-443

Beaulieu, Anne, *The Space Inside the Skull: Digital Representations, Brain Mapping and Cognitive Neuroscience in the Decade of the Brain* (Diss.; Amsterdam: University of Amsterdam, 2000)

"Bekräftelse från USA: AIDS-virus finns i Sverige [Meddelande]" *Läkartidningen* vol.81 (1984), 2788

Beresford, Thomas P, et al., "AIDS Encephalitis Mimicking Alcohol Dementia and Depression" *Biological Psychiatry* vol.21 (1986), 394-397

Berggren, Ulf, *Datortomografins framväxt och spridning: en studie av en ny teknik ur ett organisations- och branschteoretiskt perspektiv* (Lund: Studentlitteratur, 1982)

Bergstrand, G, et al., "Cardiac Gated MR Imaging of Cerebrospinal Fluid Flow" *Journal of Computer Assisted Tomography* vol.9 (1985), 1003

Bergstrand, G, et al., "Cerebrospinal fluid flow studied with gated magnetic resonance imaging during the various parts of the cardiac cycle" *Acta Radiologica. Supplementum* vol.369 (1986), 490-491

Bergström, Kjell, et al., "Magnetisk resonanstomografi fyller luckor inom radiologisk diagnostik" *Läkartidningen* vol.82 (1985), 4101-4106

Bergström, Kjell, et al., "Avbildande magnetisk resonans. Aktuellt läge och framtidsperspektiv" *Läkartidningen* vol.81 (1984), 2683-2687

Bergström, Kjell, et al., "Kärnspinnsresonans (NMR) - ny diagnostisk bildprincip med stora möjligheter" *Läkartidningen* vol.79 (1982), 4665-4667

Blume, Stuart S, *Insight and Industry: On the Dynamics of Technological Change in Medicine* (Cambridge, London: The MIT Press, 1992)

Blume, Stuart S, "Medicine, Technology and Industry" in *Companion to Medicine in the Twentieth Century,* eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000])

Boethius, Eva, "Helhetssynen - ett diffust mål för sjukvården. Människosyn och ekonomiska faktorer styr mera" *Läkartidningen* vol.80 (1983), 1185-1187

Boijsen, Erik and Bertil Persson, "Skelettartefakter och genetiska effekter undviks med kärnspinnresonanstekniken (NMR)" *Läkartidningen* vol.81 (1984), 2688-2692

Boijsen, Erik and Bertil Persson, "Skelettartefakter och genetiska effekter undviks med kärspinnsresonanstekniken (NMR)" *Läkartidningen* vol.81 (1984), 2688-2692

Bolter, Jay David and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, MA: The MIT Press, 2000 [1999])

Broström, Christina, "Hivinfekterade med långsam eller ingen sjukdomsutveckling" *Perspektiv på hiv* (2000)

Brown, Fredric, *Martians, Go Home* (New York: Bantam Books, 1955)

Burt, C Tyler, "NMR Measurements and Flow" *Journal of Nuclear Medicine* vol.23 (1982), 1044-1045

C

Calltorp, Johan, *Prioritering och beslutsprocess i sjukvårdsfrågor: Några drag i de senaste decenniernas svenska hälsopolitik* (Uppsala: Uppsala universitet, 1989)

Carlsson, Yngve, "Spri-konferens om utvärdering av medicinsk teknologi: Nödrop från politiker till läkare: Hjälp oss att "få tandkrämen i tuben igen"!" *Läkartidningen* vol.78 (1981), 4421-4424

Cartwright, Lisa, *Screening The Body: Tracing Medicine's Visual Culture* (Minneapolis, London: University of Minnesota Press, 1997 [1995])

Cederblom, Staffan, "Radiologins möjligheter vid vanliga kliniska symtom" *Läkartidningen* vol.81 (1984), 2358-2362

de Chadarevian, Soraya and Nick Hopwood (eds.), *Models: The Third Dimension of Science* (Stanford, CA: Stanford University Press, 2004)

Clarke, Adele E, "Maverick Reproductive Scientists and the Production of Contraceptives, 1915-2000+" in *Bodies of Technology: Women's Involvement with Reproductive Medicine,* eds. Ann Rudinow Saetnan, et al. (Columbus, Ohio: Ohio State University Press, 2000)

Clarke, Edwin and Kenneth Dewhurst, *An Illustrated History of Brain Function: Imaging the Brain from Antiquity to the Present* (San Francisco: Norman Pub, 1996 [1968])

Cohn, Simon, "Increasing Resolution, Intensifying Ambiguity: An Ethnographic Account of Seeing Life in Brain Scans" *Economy and Society* vol.33 (2004), 52-76

Constantinesco, A, et al., "Spatial or Flow Velocity Phase Encoding Gradients in NMR Imaging" *Magnetic Resonance Imaging* vol.2 (1984), 335-340

Crooks, L., et al., "Tomography of hydrogen with nuclear magnetic resonance" *Radiology* vol.136 (1980), 701

Crooks, L.E., et al., "Visualization of cerebral and vascular abnormalities by NMR imaging: The effects of imaging parameters on contrast" *Radiology* vol.144 (1982), 843

D

Damadian, Raymond, "Tumor Detection by Nuclear Magnetic Resonance" *Science* vol.171 (1971), 1151-1153

Daston, Lorraine and Peter Galison, "The Image of Objectivity" *Representations* (1992), 81-128

van Dijck, José, *The Transparent Body: A cultural analysis of medical imaging* (Seattle: University of Washington Press, 2005)

Doel, Ron and Thomas Söderqvist (eds.), *The Historiography of Contemporary Science, Technology and Medicine: Writing Recent Science* (London, New York: Routledge, 2006)

Drayer, BP, "Imaging of the Aging Brain. Part 1. Normal Findings" *Radiology* vol.166 (1988), 785-796

Drayer, BP, "Imaging of the Aging Brain. Part 2. Pathologic Conditions" *Radiology* vol.166 (1988), 797-806

Dumit, Joseph, *Picturing Personhood: Brain Scans and Biomedical Identity* (Princeton, N.J.: Princeton University Press, 2004)

Dussauge, Isabelle, "Questioning Medical Technology: The Discourse on Technology in *Läkartidningen* 1978-1985" *Polhem 2004* vol.1 (2005), 65-89

Dyring, Eric, "Magnetkamera läkarnas senaste hjälp: Radiovåg avbildar hjärnan" *Dagens Nyheter,* December 22, 1984

E

Englund, E, et al., "Relaxation Times in Relation to Grade of Malignancy and Tissue Necrosis in Astrocytic Gliomas" *Magnetic Resonance Imaging* vol.4 (1986), 425-429

Englund, E, et al., "Tumours of the Central Nervous System - Proton MR Relaxation T1 and T2 and Histopathologic Correlates" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 653-659

Englund, E, et al., "Correlations Between Histopathologic White Matter Changes and Proton MR Relaxation Times in Dementia" *Alzheimer´s Disease and Associated Disorders (ADAD-IJ)* vol.1 (1987), 156-170

Epstein, Steven, *Impure Science: AIDS, Activism and the Politics of Knowledge* (Berkeley, Los Angeles, London: University of California Press, 1996)

Ericsson, A, et al., "Proton Relaxation in a Multicompartmental System with Exchange, Simulating Human Tissue" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.26 (1985), 745-751

Ericsson, A., et al., "Calculation of MRI Artifacts Caused by Static-Field Disturbances" *Physics in Medicine and Biology* vol.33 (1988), 1103-1112

F

Fleck, Ludwik, *Genesis and Development of a Scientific Fact* (Chicago: University of Chicago Press, 1979 [1935])

[Forskningsnämnden vid RmC], "[Meddelande] Forskning om NMR och hälsokontroller får anslag av Cancerfonden" *Läkartidningen* vol.79 (1982), 2176

Foucault, Michel, *The Birth of the Clinic: An Archaeology of Medical Perception* (London: Routledge, 1991 [1963])

Foucault, Michel, *Naissance de la clinique* (Paris: Presses universitaires de France, 2000 [1963])

Fox Keller, Evelyn, "Models of and Models for: Theory and Practice in Contemporary Biology" *Philosophy of Science* vol.67 (2000), S72-S86

G

Galison, Peter, *Image and Logic: A Material Culture of Microphysics* (Chicago and London: The University of Chicago Press, 1997)

Gieryn, Thomas F, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists" *American Sociological Review* vol.48 (1983), 781-795

Goodwin, Charles, "Professional Vision" *American Anthropologist* vol.96 (1994), 606-633

Grant, David M. and Robin K. Harris (eds.), *Encyclopedia of Nuclear Magnetic Resonance, Vol.1* (New York: Wiley, 1996)

Greitz, D, et al., "Pulsatile Brain Movement and Associated Hydrodynamics Studied by Magnetic Resonance Phase Imaging. The Monro-Kellie Doctrine Revisited" *Neuroradiology* vol.34 (1992), 370-380

Groopman, Jerome E., "Clinical Spectrum of HTLV-III in Humans" *Cancer Research (Suppl.)* vol.45 (1985), 4649s-4651s

Györffy-Wagner, Z, et al., "Proton Magnetic Resonance Relaxation Times T1 and T2 Related to Postmortem Interval. An Investigation of Porcine Brain Tissue" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 115-118

H

Hacking, Ian, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (Cambridge: Cambridge University Press, 1997 [1983])

Haraway, Donna, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991)

Hemmingsson, A., et al., "Structure Enhancement by Subtraction in Magnetic Resonance Imaging" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 459-461

Hemmingsson, A., et al., "MR-Cholangiography with a Double Contrast Technique" *Acta Radiologica* vol.30 (1989), 29-33

Hemmingsson, A., et al., "Relaxation Enhancement of the Dog Liver and Spleen by Biodegradable Superparamagnetic Particles in Proton Magnetic Resonance Imaging" *Acta Radiologica* vol.28 (1987), 703-705

Hemmingsson, Anders and Holger Pettersson, "Magnetisk resonanstomografi - en ny dimension i diagnostisk radiologi" *Läkartidningen* vol.84 (1987), 1527-1529

Henriksen, O, et al., "In vivo evaluation of femoral blood flow measured with magnetic resonance" *Acta Radiologica* vol.30 (1989), 153-157

Herrlin, K, et al., "Gadolinium-DTPA enhancement of soft tissue tumors in magnetic resonance imaging" *Acta Radiologica* vol.31 (1990), 233-

Higgins, CB and H Sakuma, "Heart Disease: Functional evaluation with MR imaging" *Radiology* vol.199 (1996), 307-315

Ho, DD, et al., "Isolation of HTLV-III from cerebrospinal fluid and neural tissues of patients with neurologic syndromes related to the acquired immunodeficiency syndrome" *New England Journal of Medicine* vol.313 (1985), 1493-1497

Holtzmann Kevles, Bettyann, *Naked to the Bone: Medical Imaging in the Twentieth Century* (Reading, MA: Addison-Wesley, 1997)

Holtås, S, et al., "Signal alterations, artifacts and image distortion induced by a superparamagnetic contrast medium" *Acta Radiologica* vol.31 (1990), 213-216

Holtås, Stig, et al., "Magnetresonanstomografisk undersökning av ryggen - en billig och säker diagnostisk metod" *Läkartidningen* vol.84 (1987), 1544-1547

J

Jenner, Marc SR and Bertrand O Taithe, "The Historiographical Body" in *Companion to Medicine in the Twentieth Century*, eds. Roger Cooter and John Pickstone (London; New York: Routledge, 2003 [2000])

Joyce, Kelly, "Appealing Images: Magnetic Resonance Imaging and the Production of Authoritative Knowledge" *Social Studies of Science* vol.35 (2005), 437-462

Joyce, Kelly, "From Numbers to Pictures: The Development of Magnetic Resonance Imaging and the Visual Turn in Medicine" *Science as Culture* vol.15 (2006), 1-22

Jung, B., et al., "Selective Properties of Trains of Real and Complex Rf Micropulses in Slice-Selective Spin-Echo MRI" *Upsala Journal of Medical Sciences* vol.91 (1986), 37-43

Jülich, Solveig, *Skuggor av sanning: Tidig svensk radiologi och visuell kultur* (Diss.; Linköping: Linköpings universitet, 2002)

K

"Kameran som hjälper oss att se in i hjärnan" *SVAR på primärvårdsfrågor* (1986),

Karlsson, Yngve, "Ny teknik spränger radiologins gränser" *Läkartidningen* vol.80 (1983), 1331-1334

Karolinska institutets fonder (Stockholm: Broberg, 1981)

Keating, Peter and Alberto Cambrosio, *Biomedical Platforms: Realigning the normal and the pathological in late-twentieth-century medicine* (Cambridge, M.A., London, England: The MIT Press, 2003)

L

"Landstingsförbundet och MR-tekniken: "Mjukare" rekommendation accepterar fler enheter" *Läkartidningen* vol.81 (1984), 3884

Langone, John, "Nya scanners ser rakt igenom de gamla egyptierna" *Illustrerad Vetenskap* (1986), 68-71

Laqueur, Thomas, *Maxing Sex: Body and Gender from the Greeks to Freud* (Cambridge, MA; London: Harvard University Press, 1992 [1990])

Larsson, E-M, *Magnetic Resonance Imaging of the Cervical and Thoracic Spine and the Spinal Cord: A study using a 0.3 T vertical magnetic field* (Diss.; Lund, 1989)

Larsson, E-M, et al., "Regional differences in the proton MR relaxation times T1 and T2 within the normal human brain" *Acta Radiologica. Diagnosis Medical Imaging and Physiologic Radiology* vol.27 (1986), 231-234

Larsson, E-M, et al., "Emergency magnetic resonance examination of patients with spinal cord symptoms" *Acta Radiologica* vol.29 (1988), 69-75

Larsson, E-M, et al., "Coil selection for magnetic resonance imaging of the cervical and thoracic spine using a vertical magnetic field" *Acta Radiologica* vol.30 (1989), 141-146

Laurin, Sven, "Undersökning av barn med kärnspinnresonans (MRI)" *Läkartidningen* vol.82 (1985), 4112-4114

Levine, Deborah, et al., "Fetal anatomy revealed with fast MR sequences" *American Journal of Roentgenology* vol.167 (1996), 905-908

Lindberg, Bo and Staffan Meurling, "NMR och PET - speciellt lämpliga metoder för pediatrisk diagnostik" *Läkartidningen* vol.81 (1984), 2668-2669

Lindqvist, Kjell, "Ny metod för helkroppsundersökning: Kemisk analys och anatomiska bilder utan ingrepp och röntgenstrålning" *Läkartidningen* vol.77 (1980), 4278-4280

Luhrmann, TM, *Of Two Minds: An anthropologist looks at American psychiatry* (New York: Vintage Books, 2001 [2000])

"[Läkaresällskapets 82:e Riksstämma]" *Läkartidningen* vol.82 (1985), 3797-3839

"[Läkaresällskapets Riksstämma 1981: Program / Svensk förening för medicinsk radiologi och Svensk förening för radiofysik]" *Läkartidningen* vol.78 (1981), 3935-3936

"[Läkaresällskapets Riksstämma 1983]" *Läkartidningen* vol.80 (1983), 4160-4198

"[Läkaresällskapets Riksstämma 1984 - Sektionsprogram]" *Läkartidningen* vol.81 (1984), 4051-4087

"[Läkaresällskapets Riksstämma 1986]" *Läkartidningen* vol.83 (1986), 3704-

"[Läkaresällskapets Riksstämma 1987]" *Läkartidningen* vol.84 (1987), 3606-3654

"[Läkaresällskapets Riksstämma 1988]" *Läkartidningen* vol.85 (1988), 3695-3736

"[Läkaresällskapets Riksstämma 1989]" *Läkartidningen* vol.86 (1989),

"[Läkaresällskapets Riksstämma 1990]" *Läkartidningen* vol.87 (1990), 3635-3681

Lönnemark, M., et al., "Effect of superparamagnetic particles as oral contrast medium at magnetic resonance imaging - A phase I clinical study" *Acta Radiologica* vol.30 (1989), 193-196

Lönnemark, M., et al., "Superparamagnetic Particles as an MRI Contrast Agent for the Gastrointestinal-Tract" *Acta Radiologica* vol.29 (1988), 599-602

M

"Magnetisk resonanstomografi stor investering. Ännu inte helt färdig för klinisk bruk" *Läkartidningen* vol.84 (1987), 3944-3945

Martensen, Robert L, *The Brain Takes Shape: An early history* (Oxford, New York: Oxford University Press, 2004)

Mattson, James and Merrill Simon, *The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI* (Ramat Gan, Israel: Bar-Ilan University Press, 1996)

McSwain, Rebecka, "The Social Reconstruction of a Reverse Salient in Electrical Guitar Technology: Noise, the Solid Body and Jimi Hendrix" in *Music and Technology in the Twentieth Century*, ed. Hans-Joachim Braun (Baltimore, 2002)

"[Meddelande] Donation på 4 milj till "magnetkamera" vid S:t Göran" *Läkartidningen* vol.81 (1984), 2716

"Medicinsk scanner daterar helgonfigurer" *Illustrerad Vetenskap* (1990), 25

Mitchell, William J., *The Reconfigured Eye: Visual Truth in the Post-Photographic Era* (Cambridge, MA; London: The MIT Press, 2001 [1994])

Moberg, Lars, et al., "Venereologisk undersökning i Stockholm: Var tredje "frisk" homosexuell man hade behandlingskrävande infektion" *Läkartidningen* vol.81 (1984), 2747-2752

Mol, Annemarie, *The Body Multiple: Ontology in medical practice* (Durham & London: Duke University Press, 2002)

Moran, Paul R, "A flow velocity zeugmatographic interlace for NMR imaging in humans" *Magnetic Resonance Imaging* vol.1 (1982), 197-203

N

Nilsson, Ulrika, *Det heta könet: Gynekologin i Sverige kring förra sekelskiftet* (Stockholm: Wahlström & Widstrand, 2005)

NMR imaging: proceedings of an International symposium on nuclear magnetic resonance imaging : held at the Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, North Carolina, October 1-3, 1981 (1981)

Nordell, B, et al., "A rotating phantom for the study of flow effects in MR imaging" *Magnetic Resonance Imaging* vol.6 (1988), 695-705

Notman, Derek NH, et al., "Modern Imaging and Endoscopic Biopsy Techniques in Egyptian Mummies" *American Journal of Roentgenology* vol.146 (1986), 93-96

"Ny teknik känner mumierna på pulsen" *Illustrerad Vetenskap* (1993), 19

Nyman, R., et al., "An attempt to characterize malignant lymphoma in spleen, liver and lymph node with magnetic resonance imaging" *Acta Radiologica* vol.28 (1987), 527-533

"Nytt avtal klart för UAS-läkarna vid övergången till landstinget" *Läkartidningen* vol.79 (1982), 4887

O

Odeblad, Erik and Gunnar Lindström, "Some preliminary observations on the proton magnetic resonance in the biologic samples" *Acta Radiologica* vol.43 (1955), 469-476

"[Offentliga underrättelser] Första NMR-utrustningen till Akademiska sjukhuset" *Läkartidningen* vol.79 (1982), 2673

Oldendorf, William H., *The Quest for an Image of the Brain* (New York: Raven Press, 1980)

Olsson, Magnus BE, et al., "Ferromagnetic particles as contrast agent in T2 NMR imaging" *Magnetic Resonance Imaging* vol.4 (1986), 437-440

P

Pasveer, Bernike, "Knowledge of Shadows: The Introduction of X-ray images in Medicine" *Sociology of Health and Illness* vol.11 (1989), 360-381

Pasveer, Bernike, *Shadows of Knowledge. Making a Representing Practice in Medicine: X-ray Pictures and Pulmonary Tuberculosis, 1895-1930* (Amsterdam: University of Amsterdam, 1992)

Pehrson, Pehrolov, et al., "AIDS hos homosexuella män - första fallen i Sverige" *Läkartidningen* vol.80 (1983), 545-548

Persson, B, et al., "Design and application of a proton NMR imaging system based on a window frame type of magnet" in *Progress in Nuclear Medicine, vol.8: Magnetic Resonance in Medicine and Biology,* eds. MA Hopf and FW Smith (Basel: Karger, 1984)

Persson, Bertil, *Medicinska tillämpningar av kärnspinnresonans - NMR* (Lund: Studentlitteratur, 1982)

Pettersson, Holger, "Undersökning av muskuloskelettala systemet med kärnspinnresonans (MRI)" *Läkartidningen* vol.82 (1985), 4108-4111

Prasad, Amit, "Making Images/Making Bodies: Visibilizing and Disciplining through Magnetic Resonance Imaging (MRI)" *Science, Technology and Human Values* vol.30 (2005), 291-316

Prasad, Amit, "Scientific Culture in the 'Other' Theater of 'Modern Science': An Analysis of the Culture of Magnetic Resonance Imaging Research in India" *Social Studies of Science* vol.35 (2005), 463-489

Prasad, Amit, "Beyond Modern vs Alternative Science Debate: Analysis of Magnetic Resonance Imaging Research" *Economic and Political Weekly* (2006), 219-227

Prasad, Amit, "The (Amorphous) Anatomy of an Invention: The Case of Magnetic Resonance Imaging" *Social Studies of Science* vol.37 (2007), 533-560

von Proschwitz, Charlotte, "BILDEN AV AIDS", *Expressen*, June 26, 1987

Q

Reiser, Stanley Joel, *Medicine and the Reign of Technology* (Cambridge: Cambridge University Press, 1978)

Reiser, Stanley Joel, "The science of diagnosis: medicine and the five senses" in *Companion Encyclopedia of the History of Medicine,* eds. WF Bynum and Roy Porter (London; New York: Routledge, 1993)

Rennestedt, Birgit, "PS. Psykiatrins pansarkryssare" *Läkartidningen* vol.79 (1982), 952

"Risk för investeringar - Landstingsförbundet vill vänta med NMR" *Läkartidningen* vol.79 (1982), 3770

Rubin, Herbert J and Irene S Rubin, *Qualitative Interviewing: The Art of Hearing Data* (Thousand Oaks, CA; London; New Delhi: Sage Publications, 2005)

S

Sappol, Michael, *Dream Anatomy* (Bethesda, Md: U.S. Dept. of Health and Human Services, National Institutes of Health, National Library of Medicine, 2006)

Sawchuk, Kim, "Biotourism, Fantastic Voyage, and Sublime Inner Space" in *Wild Science: Reading feminism, medicine and the media,* eds. Janine Marchessault and Kim Sawchuk (New York: Routledge, 2000)

SBU, *Magnetisk resonanstomografi* (Stockholm: SBU, 1992)

Schultz, Willibrord Weijmar, et al., "Magnetic resonance imaging of male and female genitals during coitus and female sexual arousal" *BMJ* vol.319 (1999), 1596-1600

Sepponen, Raimo E, "Low-Field MR Imaging - Development in Finland" *Acta Radiologica* vol.37 (1996), 446-454

Shaw, George M., et al., "HTLV-III Infection in Brains of Children and Adults with AIDS Encephalopathy" *Science* vol.227 (1985), 177-182

Singer, JR and LE Crooks, "Nuclear Magnetic Resonance Blood Flow Measurements in the Human Brain" *Science* vol.221 (1983), 654-656

Snider, WD, et al., "Neurological complication of acquired immune deficiency syndrome: analysis of 50 patients" *Annals of Neurology* vol.14 (1983), 403-18

Sperber, G. O., et al., "NOTE - A Fast Method for T1 Fitting" *Magnetic Resonance in Medicine* vol.9 (1989), 113-117

Sperber, G. O., et al., "Fast Methods for Fitting Biexponentials Especially Applicable to MRI Multiecho Data" *Physics in Medicine and Biology* vol.35 (1990), 399-411

Sperber, G. O., et al., "Improved Formulas for Signal Amplitudes in Repeated NMR Sequences - Applications in NMR Imaging" *Magnetic Resonance in Medicine* vol.3 (1986), 685-698

SPRI, *MRT - Magnetisk resonanstomografi* (Stockholm: Spri, 1986)

SPRI, *Magnetisk resonanstomografi i Norden* (Stockholm: Spri, 1987)

Stafford, Barbara Maria, *Body Criticism: Imaging the Unseen in Enlightment Art and Medicine* (Cambridge, MA: MIT Press, 1991)

Ståhlberg, F, *MR Flow Imaging: A survey of methods for flow imaging using NMR technique*, LUNFD6/ (NFRA-3053) / (1-29) / (1984); LUMEDW/ (MERI-3053) / (1-29) / (1984), 1984

Ståhlberg, F, *NMR Flow Imaging: A Study of Flow Perpendicular to the Imaging Plane Using 0.08 - 1.5 T NMR Imaging Units* (Diss.; Lund: Lund, 1987)

Ståhlberg, F, et al., "Determination of flow velocities from magnetic resonance multiple spin-echo images. A phantom study" *Acta Radiologica* vol.28 (1987), 643-648

Ståhlberg, F, et al., "A method for MR quantification of flow velocities in blood and CSF using interleaved gradient-echo pulse sequences" *Magnetic Resonance Imaging* vol.7 (1989), 655-667

Ståhlberg, F, et al., *Flow measurements on the Lund 0.3 T FONAR unit - Preliminary results and future aspects*, LUNFD6/(NFRA-3075)/(1-13)/(1986); LUMEDW/(MERI-3075)/(1-13)/(1986), 1986

Ståhlberg, F and B Persson, *Flödesmätningar på dialysatorer med scintillationskamera- och NMR (kärnspinnresonans)-teknik*, LUNFD6/ (NFRA-3046) / (1-30) / (1984); LUMEDW/ (MERI-3046) / (1-30) / (1984), 1984

Ståhlberg, Freddy and Lars Herrnsdorf, "En metod för flödesmätningar med hjälp av NMR-teknik [Poster]" in *Läkaresällskapets Riksstämma 30 nov-2 dec 1983: Program och sammanfattningar (Svenska läkaresällskapets handlingar 92 (1983):8)*, 1983)

Svendgaard, Niels-Aage, "Magnetkameran ser mer än kirurgen" *Läkartidningen* vol.94 (1997), 1978-1979

Söderqvist, Thomas, "Existential projects and existential choice in science: science biography as an edifying genre" in *Telling lives in science: essays on scientific biography,* eds. Michael Shortland and Richard Yeo (Cambridge: Cambridge University Press, 1996)

Söderqvist, Thomas (ed.) *The Historiography of Contemporary Science and Technology* ([Amsterdam], The Netherlands: Harwood Academic Publishers, 1997)

Sönnerborg, A, et al., "Quantitative detection of brain aberrations in human immunodeficiency virus type 1-infected individuals by magnetic resonance imaging" *The Journal of Infectious Diseases* vol.162 (1990), 1245-1251

Sönnerborg, Anders and Lennart Wetterberg, "HIV-infektion i nervsystemet - patogenes, klinik och diagnostik" *Läkartidningen* vol.85 (1988), 1053-1055

T

"[Table of contents]" *Läkartidningen* vol.83 (1986), [4137]

Thomsen, Carsten, et al., "Fourier Analysis of Cerebrospinal Fluid Flow velocities: MR Imaging Study" *Radiology* vol.177 (1990), 659-665

Thuomas, Karl-Åke, *Aspects of Image Intensity and Relaxation Time Assessment in Magnetic Resonance Imaging: An experimental and clinical study* (Diss.; Uppsala, 1987)

Thuomas, KÅ, et al., "Subtraction in magnetic resonance imaging" *Acta Radiologica. Supplementum* vol.369 (1986), 483-485

Tovi, M, et al., "Delineation of gliomas with magnetic resonance imaging using Gd-DTPA in comparison with computed tomography and positron emission tomography" *Acta Radiologica* vol.31 (1990), 417-429

Tovi, M, et al., "Tumour delineation with magnetic resonance imaging in gliomas. A comparison with positron emission tomography and computed tomography" *Acta Radiologica. Supplementum* vol.369 (1986), 161-163

U

Udén, Rolf, et al., "Serafenprojektet" *Läkartidningen* vol.77 (1980), 106-126

W

Wahlund, Lars-Olof, et al., "Magnetic Resonance Imaging (MRI) in Psychiatry: Experience of 731 patients" in *Magnetic Resonance Imaging of the Brain in Healthy Individuals and Neuropsychiatric Patients: Morphological studies and tissue characterization,* ed. Ingrid Agartz (Stockholm, 1992)

Wahlund, Lars-Olof, et al., "Magnetisk resonanstomografi inom psykiatrin - sjukvårdsmässiga vinsterna uppenbara" *Läkartidningen* vol.86 (1989), 3991-3994

Wahlund, L-O, et al., "The brain in healthy aged individuals: MR imaging" *Radiology* vol.174 (1990), 675-679

Wahlund, L-O, et al., "The installation of a commercial 0.02 Tesla magnetic resonance imager" *International Journal of Technology Assessment in Health Care* vol.1 (1985), 766-771

Wahlund, L-O, et al., "MRI in psychiatry: 731 cases" *Psychiatry Research* vol.45 (1992), 139-140

Waldby, Catherine, "The Visible Human Project: Data into flesh, flesh into data" in *Wild Science: Reading feminism, medicine and the media,* eds. Janine Marchessault and Kim Sawchuk (New York: Routledge, 2000)

Waldby, Catherine, *The Visible Human Project: Informatic Bodies and Posthuman Medicine* (London; New York: Routledge, 2000)

Weimarck, Torsten, "Kroppen, och den anatomiska kroppen" in *Kroppen: Konst och vetenskap,* ed. Lena Holger (Stockholm: Nationalmuseum, 2005)

Wetterberg, Lennart (ed.) *Svenska studenter i Los Angeles: ett experiment för att internationalisera utbildningen i psykiatri [Swedish students in Los Angeles: an experiment in order to internationalize education in psychiatry]* (Stockholm: Psykiatriska kliniken, Karolinska institutet, 1979)

Wetterberg, Lennart, "Medicinsk kommentar - Vad kan vi vänta oss av "magnetkameran"?" *Läkartidningen* vol.81 (1984), 2659-2660

Wetterberg, Lennart, "Vad kan vi vänta oss av 'magnetkameran'?" *Läkartidningen* vol.81 (1984), 2659-2660

Wetterberg, Lennart, "Ny princip prövas vid behandling av AIDS. Peptid kan blockera cellers receptor för HIV" *Läkartidningen* vol.83 (1986), 4189-4191

Wetterberg, Lennart, *De första 30 åren: 1961-1991: Psykiatriska kliniken, S:t Görans sjukhus* ([Stockholm]: [Psykiatriska kliniken, S:t Görans sjukhus], 1991)

Wikström, M., et al., "Magnetic resonance imaging of acute myocardial infarction in pigs using Gd-DTPA" *Acta Radiologica* vol.31 (1990), 619-624

Winge, Sören, "Stora kameralyftet på Akademiska sjukhus", *Uppsala Nya Tidning*, August 29, 1984

Y

Yoxen, Edward, "Seeing with Sound: A Study of the Development of Medical Images" in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology,* eds. Wiebe E Bijker, et al. (Cambridge, Mass.: MIT Press, 1997 [1987])

Å

Åhrén Snickare, Eva, *Döden, kroppen och moderniteten* (Stockholm: Carlsson, 2002)